



NAVAL FACILITIES ENGINEERING SERVICE CENTER
Port Hueneme, California 93043-4370

Technical Report
TR-2075-ENV

Technology Transfer Report:
Production Base Catalyzed
Decomposition Process
Guam, Mariana Islands



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October 1997

19980130 104

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REPORT DOCUMENTATION PAGE		Form Approved OMB No. 0704-018	
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.</p>			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1997	3. REPORT TYPE AND DATES COVERED Final; October 1992 - June 1997	
4. TITLE AND SUBTITLE TECHNOLOGY TRANSFER REPORT: PRODUCTION BASE CATALYZED DECOMPOSITION PROCESS GUAM, MARIANA ISLANDS		5. FUNDING NUMBERS	
6. AUTHOR(S) Benoit, Gallagher, Chan, Fukumoto, Crisostomo			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(E(S)) Naval Facilities Engineering Service Center 1100 23rd Avenue Port Hueneme, CA 93043-4370		8. PERFORMING ORGANIZATION REPORT NUMBER TR-2075-ENV	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESSES Naval Facilities Engineering Command 200 Stovall Street Alexandria, VA 22332		10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.		12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The first product base catalyzed decomposition process (BCDP) operated successfully on Guam April 1996 to June 1997. The unit treated 11,700 tons of soil at PCB levels over 2,000 ppm to below 0.05 ppm at rates up to 2 tons per hour. A novel air control system produces a stack gas cleaner that required by hazardous waste incinerators. The Naval Facilities Engineering Service Center managed the development of the unit for the Navy's Pacific Division from the laboratory to a full production system over an 8-year period. Conventional remediation on Guam would have required that the contaminated material be placed in drums and shipped over 6,000 miles to a mainland disposal facility -- a very expensive procedure. In finding a solution to this problem, the Navy created a remediation system that is cost-effective on the mainland as well as Guam, and environmentally safe to operate.			
14. SUBJECT TERMS Hazardous waste, base catalyzed decomposition process, remediation, stack gas cleaner, incinerators		15. NUMBER OF PAGES 379	
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

Executive Summary

The first production Base Catalyzed Decomposition Process (BCDP) system was operated successfully on Guam in 1995. The unit treated polychlorinated biphenyl (PCB) contaminated soil at rates up to two tons per hour, and successfully treated 11,700 tons of soil at PCB levels as high as 2,000 parts per million (ppm) to below 0.5 ppm. A novel Air Pollution Control System (APCS) produced a stack gas that was cleaner than required by hazardous waste incinerators standards.

The Naval Facilities Engineering Service Center (NFESC) managed the development of the BCDP for the Naval Facilities Engineering Command, Pacific Division (PACDIV) from the laboratory to a full production system over a 6-year period. Conventional remediation on Guam would have required that the contaminated material be excavated, placed in drums, and shipped over 6,000 miles to a mainland disposal facility — a very expensive procedure. In finding a solution to this problem, the Navy developed a remediation system that is cost effective, on the mainland as well as Guam, and environmentally safe to operate.

The soil to be treated is crushed, mixed with sodium bicarbonate, and fed into an indirectly fired Rotary Kiln Reactor (RKR). In the RKR, the PCBs and naturally occurring organics are driven off the soil at temperatures up to 800 degrees Fahrenheit ($^{\circ}$ F). The bicarbonate catalyzes this process by decomposing some of the PCBs and causing them to desorb at reduced temperatures.

The innovative air capture system starts in the calciner where steam is injected as the sweep gas to carry out the desorbed PCBs. The oxygen content in the calciner is too low to support combustion, so there is no danger of combustion occurring and creating an overpressure that would result in the release of contaminants from the calciner.

The RKR off-gas moves through a cyclone to remove larger dust particles, and then into a Wet Electrostatic Precipitator (WESP) where almost all the contaminants are removed. Despite the presence of organic combustibles, the precipitator can be operated safely because oxygen levels are kept too low to support combustion. Additional steam is injected into the WESP as necessary to maintain the oxygen level in the gas being handled to below 5 percent. Since oxygen is required to form dioxins, low oxygen levels in the process also inhibit the formation of these undesirable compounds.

When the gas exits the WESP it passes through a shell-and-tube heat exchanger where the steam is condensed. In addition to maintaining low oxygen levels, another great advantage of using steam as an inerting gas is that it can easily be removed from the gas stream. Gas leaves the condenser at about 80°F. For final polishing, the off-gas is chilled to 40 to 50°F and passes through a High Efficiency Mist Eliminator (HEME) and a Carbon Adsorber. Very little PCB buildup occurs in the Carbon Adsorber because most of the PCBs have been condensed and removed as a liquid. Because the WESP removes most of the PCBs and other condensable organics, the HEMEs and Carbon Adsorbers have very long lives.

The system is environmentally safe. If the WESP should go off-line because of a power or equipment failure, the off-gas still has to pass through the HEME and will be almost as clean as with the WESP on-line. Although the life of the HEME will be shortened, no significant emission excursion can occur.

A stack test, conducted while the BCDP was treating almost 2 tph of soil, showed that the stack gas flow was under 30 cubic feet per minute (cfm). PCB Destruction Removal Efficiency (DRE) was 7 nines (or 99.9999 percent), and the dioxin and furan Toxic Equivalent (TEQ) was 0.18 nanograms per cubic meter. Metals were not measured, and the laboratory results for the particulate analysis were not reliable, however, particulates emissions were conservatively reported at 3 pounds a year. Particulate and metals emissions should be almost non-existent since the off-gas passes through the HEME (which is a three-inch-thick tightly woven filter) at 40 to 50°F prior to discharge.

This Technology Transfer Report briefly describes the history of the BCDP and provides references to the research and demonstration plant work that lead directly to the final remediation system. Plant design information and operating data are provided in sufficient detail for the technology to be reproduced. A complete process design package, including Process Flow Diagrams (PFD) and material balances, Piping and Instrumentation Diagrams (P&ID), and a Plot Plan of the system on Guam, are included. An economic analysis was performed and provides a summary of the actual costs associated with the Guam BCDP and projected costs for future similar projects. The Appendices contain the Standard Operating Procedures (SOP) used on Guam, analytical results, and equipment data logs that were collected during the remediation.

As with any first-of-a-kind plant, a number of things were learned that should be incorporated into the next generation BCDP plant. Based on the lessons learned on Guam, the next generation BCDP

could cost less to build and operate, and could operate more efficiently and with even lower stack emissions. The Economic Analysis Section of this report (Section 4.0) discusses the economic improvements that can be achieved. The Conclusions and Recommendations Section (Section 6.0) discusses design changes that can be made to achieve increased operating efficiency and significantly lower operating costs.

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The authors gratefully acknowledge the continuous program support provided to the BCDP remediation project by PACDIV: Eric Torngren, Leighton Wong, Darlene Ige, Carl Shimazu, previous RPMs Roy Chagi and Bill Leary.

Others:

This undertaking began in October 1992 with the contracting effort and concluded site work in June 1997. Many talented individuals from diverse fields provided their highest level of support to the project. The following people are acknowledged for contributing their exceptional experience to this project:

- **NFESC:** Rebecca Biggers, Jeff Heath, Steve Eikenberry, Sherrie Larson, Paul McDaniel, Robert Nash, Manuel Perez, Bonnar Quint, Robert Saunders, Charles Schulz, and S. Laura Yeh.
- **OICC Marianas:** Bennett Terlaje and Joe Lujan.
- **PWC Guam:** Jess Lizama, Frank Caluya, and Al Poblete.
- **Fena Laboratory:** Gorman Dorsey and Danny Agar.
- **EPA NRMRL:** Terrence Lyons, Garry Howell, George Huffman
- **NAVFACCO:** Raymond Brothers, Sheila Oxender, and Katherine Volpe.

Acknowledgments (continued)

- **IT Corporation:** Steve Bule, Debra Borkovich, Bill Clawson, Lyle Clinansmith, Dan Cooper, Mary Jo Cunningham, William Cunningham, Dennis Deffenbaugh, Frank Deklavar, Randy DeSautell, Celia Doner, Greg Fewell, Cindy Gibson, Jason Gibson, Sheila Green, John Haltom, Dan Hudson, Tony Hudson, Jeff Johnston, William Kauth, Vince Kvietkus, Mike Lane, Dave Marti, Tim Mitchel, Eddie Moore, Jeffery Moore, Doug Nelson, Warren Niederhut, Scott Petrikovic, Jim Pollard, Mike Pomposelli, Earl Seeber, Tom Southern, Roger Stansbury, Rick Stevens, Dan Thompson, and Enzo Zoratto.
- **PNNL:** Mike Brown and Andy Schmidt.
- **Others:** Jack Carpenter, Dr. Barbara Cho, Aaron Hasner, and Edward Todd.

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1.0 Introduction

This section provides an overview, and discusses the history of the Base Catalyzed Decomposition Process (BCDP) remediation technology used on Guam.

1.1 Project History

Building 3009 at Naval Station Guam was the facility used for electrical transformer maintenance for the entire Western Fleet after World War II [6]. Until 1977, when the hazards associated with polychlorinated biphenyls (PCB) were recognized and U.S. Environmental Protection Agency (EPA) began to regulate PCBs under the Toxic Substances Control Act (TSCA), significant soil contamination occurred around the building. Floor drains ran into an underground pipe that discharged into a drainage ditch north of Building 3009. Figure 1-1 shows the building and areas of PCB contamination remediated by the BCDP.

Conventional remediation technologies would require the Navy to ship the contaminated soil to the mainland for incineration or landfill. Because international shipping of hazardous waste overseas is restricted and very expensive, Naval Facilities Engineering Command, Pacific Division (PACDIV) looked for on-site treatment technologies as alternatives. At that time, late 1980s, none were available. PACDIV then turned to the Naval Civil Engineering Laboratory (NCEL) for help in developing an on-site remediation technology. Two separate Naval commands, the Naval Energy and Environmental Support Activity (NEESA) and NCEL, merged to form the current Naval Facilities Engineering Service Center (NFESC) in October 1993.

NFESC had been working with a technology developed by the EPA's Risk Reduction Engineering Laboratory (RREL) that utilized potassium polyethylene glycol (KPEG) to dechlorinate PCBs in soil. In June 1988, a pilot scale KPEG chemical dechlorination demonstration was conducted at Building 3009. The reactor was a 75 horsepower steam jacketed mixer with a 65 cubic feet working capacity. A typical batch consisted of 3,400 pounds of soil, 1,555 pounds of 400 molecular weight polyethylene glycol (PEG-400), and 285 pounds of potassium hydroxide (KOH). The batch was heated to 300 degrees Fahrenheit ($^{\circ}$ F) and held at that temperature for four to six hours.

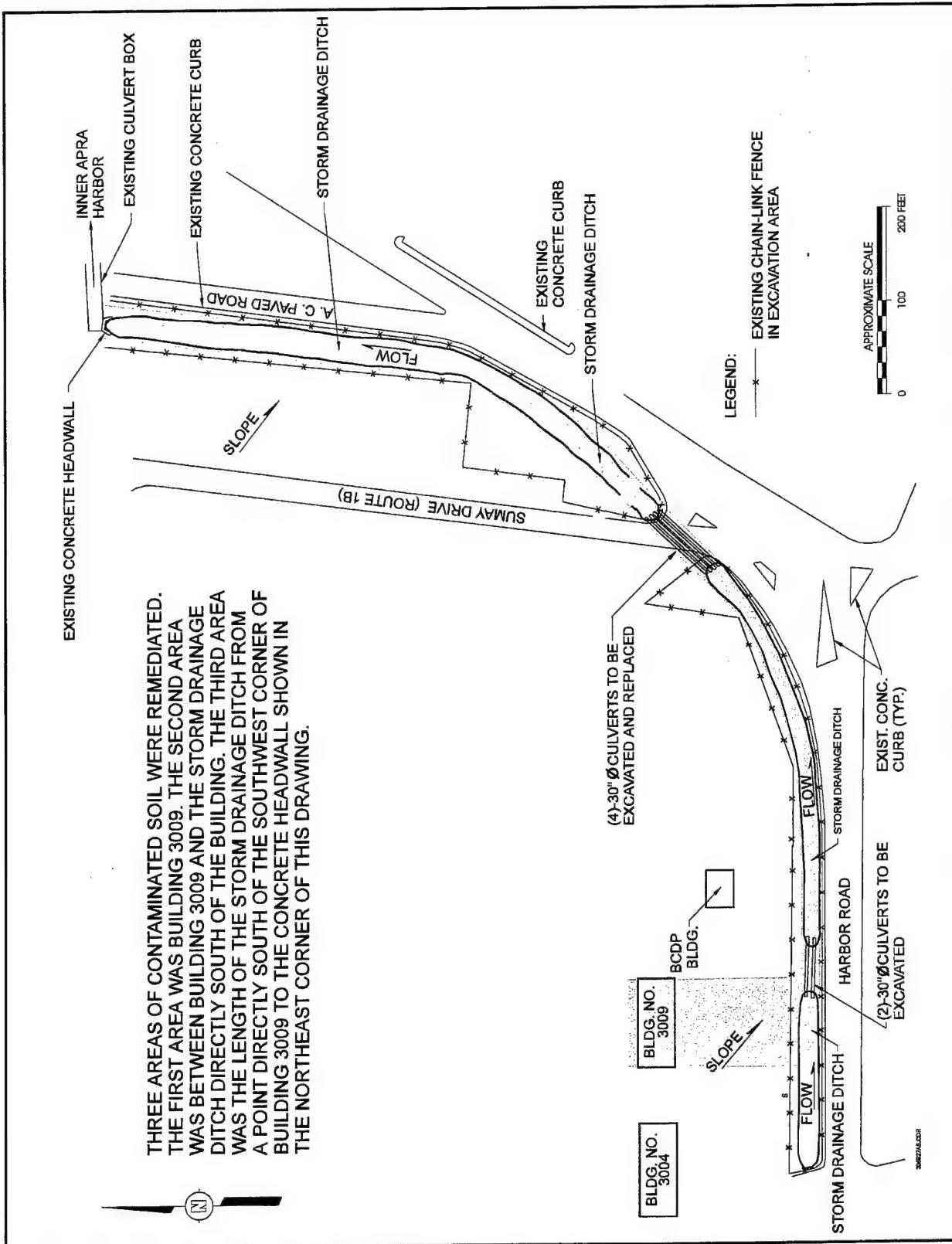


Figure 1-1
Building 3009 and Areas Remediated Using the BCDP

KPEG successfully treated soil averaging 3,535 parts per million (ppm) PCBs. PCB concentrations were reduced by an average of 99.84 percent (99.58 percent to 99.98 percent). No congener group exceeded 2 ppm. Although successful in treating soil, the demonstration runs identified several deficiencies in the KPEG process; expensive reagents added to the soil could not be recovered for reuse without great difficulty (which added significantly to the operating cost), and the process would need to be converted from batch to continuous in order to achieve satisfactory production rates.

In response to these deficiencies with KPEG, RREL initiated work on a second generation process called the BCDP. The BCDP was superior to the KPEG process. Upon NFESC's recommendation, PACDIV decided to use this process to remediate the site at Building 3009.

The strategy for remediating the site using the BCDP was to have a Research and Development (R&D) contractor design, build, and start up a demonstration unit on Guam. Once it was operating and proven, it would be turned over to a Remediation Contractor who would operate the plant and complete the remediation. Funding for the project was provided by PACDIV, and contractor technical oversight was provided by NFESC.

The U.S. Department of Energy's (DOE) Pacific Northwest National Laboratory (PNNL) was selected as the Demonstration Contractor. PNNL started equipment procurement in 1990, and assembled and tested the equipment at their facility in Washington State and at the Battelle Columbus facility in Ohio. A pre-deployment test was conducted at a Naval facility in Stockton, California, and in late 1992 the equipment was shipped to Guam.

In 1992 the Navy selected IT Corporation (IT) as the Remedial Action Contractor. IT was involved with the equipment testing and start-up to learn how to operate the equipment.

The first operation of the system was in July 1993, when about 30 tons of uncontaminated soil was processed (a "cold run") to provide a mechanical check of the system. The first PCB-contaminated soil, about 10 tons, was treated during a "hot run" in February 1994. In November of 1994, an extended hot run successfully treated about 50 tons of contaminated soil. In December 1994, the operation of the BCDP was turned over to IT. Changes were made to optimize equipment production for the remediation phase of the project. A crew mobilized to the site in January 1995,

and began the work of converting the system from a demonstration to a production unit. Major equipment modifications were made in the field while new equipment was procured.

Procurement of new equipment controlled the project schedule, and would not be completed until late 1995. Though there was no Feed Preparation Building and only a partial Air Pollution Control System (APCS), enough equipment had been received and installed by July 1995 to operate the plant. While awaiting delivery of the remaining APCS equipment, the plant was operated from early July through mid-September and processed about 600 tons of contaminated soil.

From September 1995 until February 1996 the remaining equipment was installed. The plant was operational in February and March as equipment was started up and debugged. By April, the plant was in full operation.

1.2 Technology Description

The BCDP consists of two separate processes: a solid treatment phase, the Rotary Kiln Reactor (RKR), and a liquid treatment phase, the Stirred Tank Reactor (STR). The RKR drives the PCBs off the soil and achieves partial destruction of the PCBs. The PCBs that are desorbed are condensed and collected in the RKR's APCS.

1.2.1 Stirred Tank Reactor

At the beginning of the project the intent was to treat the residual PCBs in the STR. Significant modifications were required to convert the RKR from a demonstration to a production unit. The modifications required to convert the STR to a production unit were also significant. Because of site-specific conditions, specifically the low volume of residuals created by the RKR, it was more cost effective to ship the residuals to the mainland for final disposal than to convert the STR to a production unit and use it to treat the residuals. A detailed description of the successful STR demonstration runs can be found in PNNL's report [6] covering the demonstration runs.

1.2.2 Rotary Kiln Reactor System

Figure 1-2 shows a general schematic of the BCDP process. Soil is crushed, mixed with bicarbonate, and introduced into the RKR. The RKR in Guam is a standard calciner with a carbon steel inner shell. As soil passes through the rotating shell, diesel burners heat the outside of the shell to about 900°F. The soil passing through the unit is heated above 700°F. PCBs and other organics partially decompose, and the remaining PCBs and organics volatilize into a vapor and enter the headspace

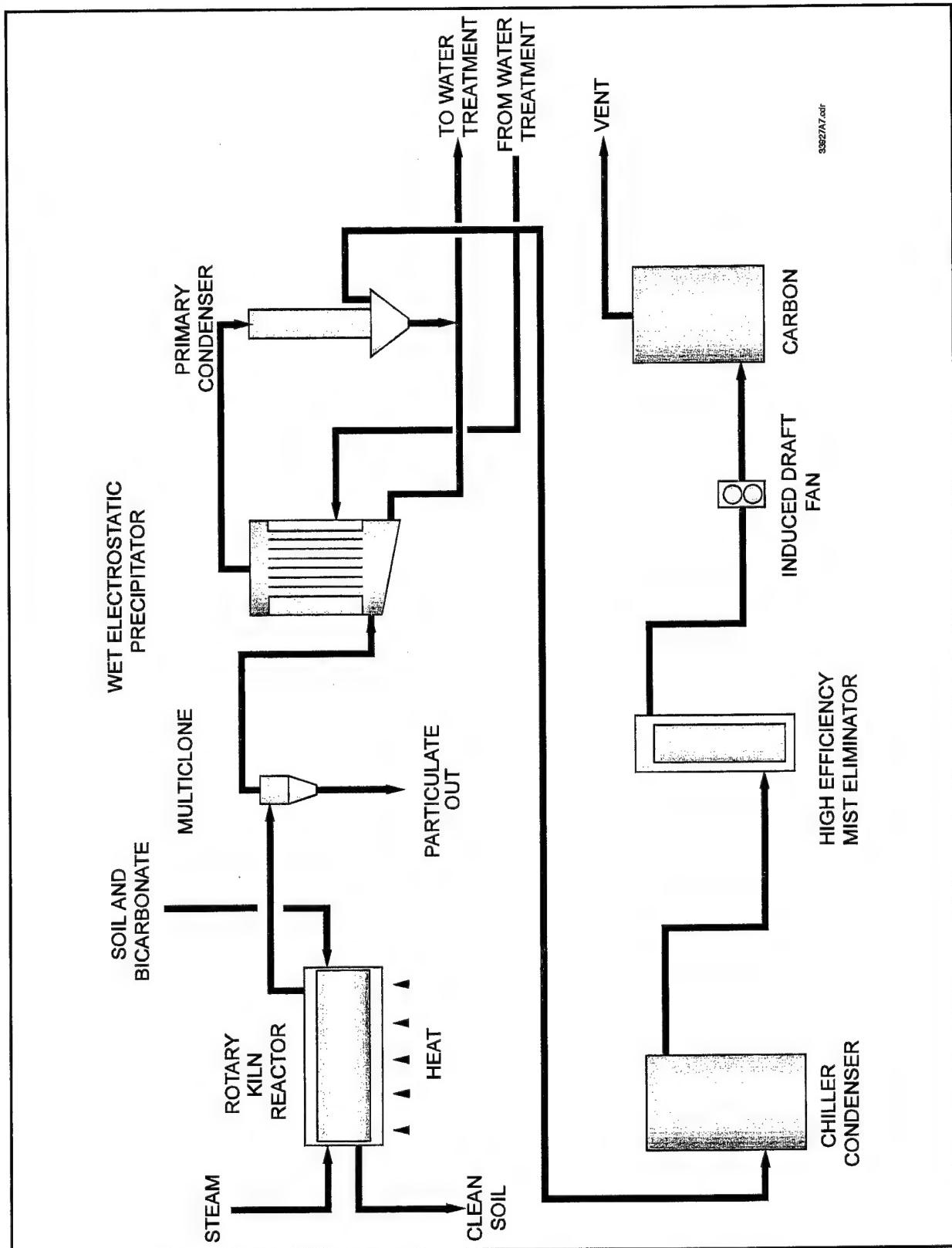


Figure 1-2
The BCDP Rotary Kiln Reactor and Air Pollution Control System

in the interior of the shell. Steam is introduced into the RKR opposite the soil feed end and moves through the shell countercurrent to the soil flow. As organics leave the solid phase and enter the gas phase in the RKR, the steam sweeps them out of the RKR to the Multicloner. Larger dust particles are removed in the Multicloner by centrifugal force and fall out, where they are collected in a drum for subsequent disposal.

The gas passes through the Multicloner to the Wet Electrostatic Precipitator (WESP). The gas continuously cools as it exits the RKR until it enters the WESP. As the gas cools, heavy semivolatile organics condense and form an aerosol (micron and submicron size droplets of organic liquid). When the gas enters the WESP, the aerosols and particulate are given an electrostatic charge. They then pass through a vertical tube sheet. The tubes in the tube sheet are charged opposite to the particles in the gas. This attracts the particulate and aerosols in the gas to the tube walls. As these solid particulates and liquid aerosols contact the walls of the tube, they agglomerate and are washed off by water which is constantly sprayed into the tubes. The WESP is almost 100 percent efficient at removing particulates and aerosols above three microns in size and 99 percent efficient in removing particulates and aerosols less than three microns in size.

Although the WESP is ideally suited for removing these small particles, this is the first application of a WESP in this configuration. Because of the strong electrostatic charges within the WESP, up to 40,000 volts, the WESP periodically sparks. This spark provides an ignition source, and if the gas in the WESP is within flammable or explosive limits, a fire or explosion could result. In the BCDP, steam is used to exclude oxygen from the WESP. By maintaining an oxygen level below 5 percent, the WESP can be safely operated with any level of organics in the entering gas stream.

The gas exiting the WESP is very clean. It is essentially free of particulates and organics that will condense at 212°F. This gas stream then enters the Primary Condenser where the steam is condensed. The Primary Condenser is a vertical shell and tube heat exchanger using cooling tower water on the shell side. The temperature of the gas is dropped from 212°F to 80-90°F, thereby condensing and removing almost all of the steam. After the steam is condensed and removed in the Primary Condenser, the only gases left are air that has infiltrated the system together with any non-condensable gases that were generated in the RKR. In the BCDP on Guam, about 130 actual cubic feet per minute (acf m) of gas enters the Primary Condenser. The gas flow leaving the Primary Condenser is about 30 acfm, a 75 percent reduction in gas volume due to cooling and condensation.

This reduced gas volume allows a corresponding size reduction in the remaining components of the system. This feature is unique to the BCDP system on Guam.

The off-gas leaving the Primary Condenser passes to the Chiller Condenser. The Chiller Condenser is a heat exchanger using an ethylene glycol water solution on the tube side. In this unit, the gas is cooled to about 40°F. This condenses additional organics and additional water.

The gas leaves the Chiller Condenser and travels to the High Efficiency Mist Eliminator (HEME). The HEME is a tightly woven fiberglass pad about three inches thick. As the gas passes through this pad, organic aerosols (that condensed because of the additional cooling after the WESP) are removed. The removal efficiency of the HEME is similar to the WESP, virtually 100 percent efficient on particles above three microns and over 99 percent efficient on particles less than three microns in size.

Although the HEME and WESP both remove the same type of material, they do so by very different mechanisms and are positioned in the APCS to compliment each other. Solid particulate and aerosols are collected on tube walls in the WESP and flushed off with water. While the HEME can remove solid particulate, the particulate will not drain out of the fabric. If particulate steadily accumulates on the surface of the HEME, it will eventually plug the fabric. Low viscosity organics that collect in the HEME will drain out of the unit, however, high viscosity organics will not drain and would accumulate and plug the HEME. The high viscosity organics and particulates that the HEME does not handle are previously removed in the WESP.

The HEME serves two major functions. It collects the organic aerosols that have formed after the cooling in the gas stream between the WESP and the HEME, and it acts as a backup should the WESP experience a power outage. The HEME is very close to being a fail-safe device. If the WESP should stop functioning, the HEME will receive the high viscosity organics and particulate and will remove them with the same efficiency seen in the WESP. They will, however, slowly plug the HEME until the pressure drop becomes excessive and the HEME has to be taken off-line. For this reason, two HEME units are configured in parallel. If one unit should plug, the gas stream is switched to the second unit and the first unit is changed out. While the WESP is operating, the HEME will receive a solids-free gas stream containing low viscosity organic aerosols. Under these conditions, the HEME has a very long service life.

After the HEME, the gas passes through the Induced Draft (ID) Fan. This Fan draws gases from the RKR through the entire APCS. Because the gas volume is significantly reduced in the Primary Condenser, the ID Fan capacity is very small. The WESP is a very low pressure drop device and the HEME, operated with low air flow, is also a low pressure drop device. In Guam, the ID Fan pulls a vacuum of only two to three inches of water.

After the ID Fan, the gas passes through the final polishing Carbon Adsorber and out the vent stack. The Carbon Adsorber will remove residual organic vapors, including residual PCB vapors that still exist even at the ambient temperature at which the carbon operates. Because of the Chiller Condenser, the Carbon Adsorber receives a dry gas stream. The gas leaving the Primary Condenser is water saturated. When this gas is cooled down to 40 degrees in the Chiller Condenser, it is still water saturated, however, after it leaves the Chiller Condenser, it heats up due to the ambient temperature. The lowest ambient temperature on Guam is about 65°F. Without the Chiller Condenser, this gas stream would still be cooling as it passed through the Carbon Adsorber and would deposit water on the carbon. By running the Carbon Adsorber dry, its adsorption capacity is significantly increased.

1.3 Remediation on Guam

The project went through three distinct work phases to remediate the Building 3009 site. The first phase of the job was to modify the BCDP demonstration plant into a remediation plant. The second phase was unanticipated. Because of equipment delivery schedules and the need to remediate an area at the site to erect the Feed Preparation Building, the partially-constructed BCDP system was operated for about two months. The third work phase was site remediation using the full scale system.

1.3.1 Demonstration to Production System

The BCDP went from the laboratory to a successfully demonstrated system on Guam over a period of about 5 years, from 1989 to 1994. The conversion of the system from a demonstration unit to a production unit covered a 3-year period from mid-1993 to February 1996. In December 1994, when the Remediation Contractor was given physical control of the system, an intense program began to convert the BCDP demonstration unit to a production unit.

The conversion work can be divided into two broad areas. Physical changes and additions were made to improve safety, increase production rates, and reduce the manpower required to operate the plant, and the APCS was redesigned and rebuilt.

1.3.1.1 Plant Physical Changes

Feed Preparation Building. During demonstration runs, the crusher and soil stockpile areas were outside. Guam gets about 90 inches of rain a year, and it is impossible to keep the reactor feed soil dry unless it is under roof. Wet soil presents a number of problems. It bridges in the reactor feed conveyor hopper, and at times was so wet it actually ran off of the feed conveyor belt. The soil is fed to the reactor through a double knife gate valve system. If wet soil is fed rapidly it packs up and plugs these valves requiring an operator to manually unplug the valve path. This actually limits the production rate to around half a ton per hour (tph) because the soil cannot be fed faster without repeated plugging.

The Demonstration Contractor recognized this problem and at the last demonstration run in November 1994 constructed a small sprung steel building to protect the soil from the rain. For the production runs, a prefabricated temporary storage facility (the Feed Preparation Building) was constructed to house the crusher, reactor feed hopper, and a large inventory of dry crushed soil. Soil crushing was only done when the soil was dry.

Although the crushing operation was not very dusty (because of the nature of the soil at the site), crushing contaminated soil is normally done in an enclosed building to prevent contaminated dust from being released into the air as a fugitive emission. Normally, a Feed Preparation Building is ventilated at four or five air changes per hour, and the exhaust air is filtered. Because of the absence of dusting, that was not necessary at this site.

Rotary Kiln Reactor Relocation. The RKR was relocated closer to the Feed Preparation Building so it could be fed directly from the building.

Reactor Product Storage Bins. The Demonstration Contractor collected the reactor product in metal bins that held about two tons of treated soil. This meant that at least once every two hours the bins had to be rotated. Not only is this labor intensive, but the work requires that the product be

stored in a temporary storage area while the laboratory determines whether or not the product quality met the regulatory treatment standard.

Twenty-four hour composites of the RKR product were analyzed to verify that the material was clean enough to backfill. The analysis took several hours, so sufficient space had to be provided to store 24 to 48 tons of material while waiting for the analytical results. Since production continued while the composite was being analyzed, a separate storage area had to be provided for this additional production. Three permanent storage bins were built to accomplish these objectives (i.e., provide surge capacity needed for sampling).

Radial Stacker Conveyor. The reactor product conveyor used during the production runs was replaced for several reasons. It was not long enough to move product from the reactor to the new storage bins, it was not mounted on wheels so it could easily be moved between storage bins, and it did not have the capacity to move two tph of reactor product. A new conveyor was purchased to solve these deficiencies.

Sample Collection/Decontamination Areas. An additional concrete slab was poured between the RKR and the Feed Preparation Building. Sumps were installed to collect potentially contaminated storm water and to provide boot wash areas. Sheds were constructed in the process areas for the storage of protective clothing and sampling equipment, including a refrigerator to store composite samples.

Control Room and Instrumentation. A 20-foot connex used for equipment shipping was converted to a control room, and a new computer control system was installed. The previous control system software was custom-written for the demonstration unit, was not suitable for long-term operation, and was not compatible with new system equipment. Off-the-shelf software has recently been developed and was procured for the reconfigured BCDP. The new software permits incorporation of new system components and allowed for alarms to be installed for critical operating parameters. Also, control systems were added so operating conditions could be monitored and changed from the control room, if required.

Laboratory. An on-site laboratory was built and equipped to handle the production samples.

Catwalks and Platforms. Occupational Safety and Health Administration (OSHA) approved ladders and platforms were built to allow safe access to points where plugs could occur in the soil feed system. The operating platform that ran along the side of the RKR was expanded and covered to provide protection from the sun and rain.

Secondary Containment. Tanks and equipment that held contaminated water were provided with secondary containment. Some of this equipment was moved into an existing 30-foot-by-40-foot building at the site. Equipment that would not fit into this building was diked, and sump pumps were installed to remove water that accumulated in the dikes.

Water Treatment Plant. A water treatment plant was required to treat process water from the new APCS, water generated during equipment decontamination and washdowns, and potentially contaminated storm water.

1.3.1.2 Air Pollution Control System

The APCS on the demonstration system did not perform as designed, but the knowledge gained from the demonstration runs was instrumental in the successful redesign efforts for the production unit.

Figure 1-3 shows the demonstration APCS. RKR off-gas first went through a cyclone where the larger particulate (>10 microns in size) was removed. The gas then flowed through a baghouse using high temperature bags where almost all remaining particulate was removed. Dilution air was bled into the off-gas as it left the kiln to maintain the temperature at the baghouse below 250°F. Higher temperatures could damage the high temperature bags. From the baghouse, the off-gas passed through a water Venturi Scrubber and Bubble Tray Scrubber. The water in the scrubbers cooled the gas and removed some condensed oils and particulate. From the scrubbers, the off-gas passed through a 3,600 revolutions per minute (rpm) centrifugal fan, two Carbon Adsorber canisters, and out the vent stack. A throttling valve at the inlet of the fan controlled the gas flow to maintain a pre-set vacuum in the kiln.

Two major problems occurred with the demonstration system: 1) baghouse failure, and 2) lack of complete capture of PCBs and organics. When the bags in the baghouse became wet with condensed organics, the particulate that was being trapped became wet, causing the bags to plug. The system components beyond the baghouse did not stop the condensed organics and PCBs.

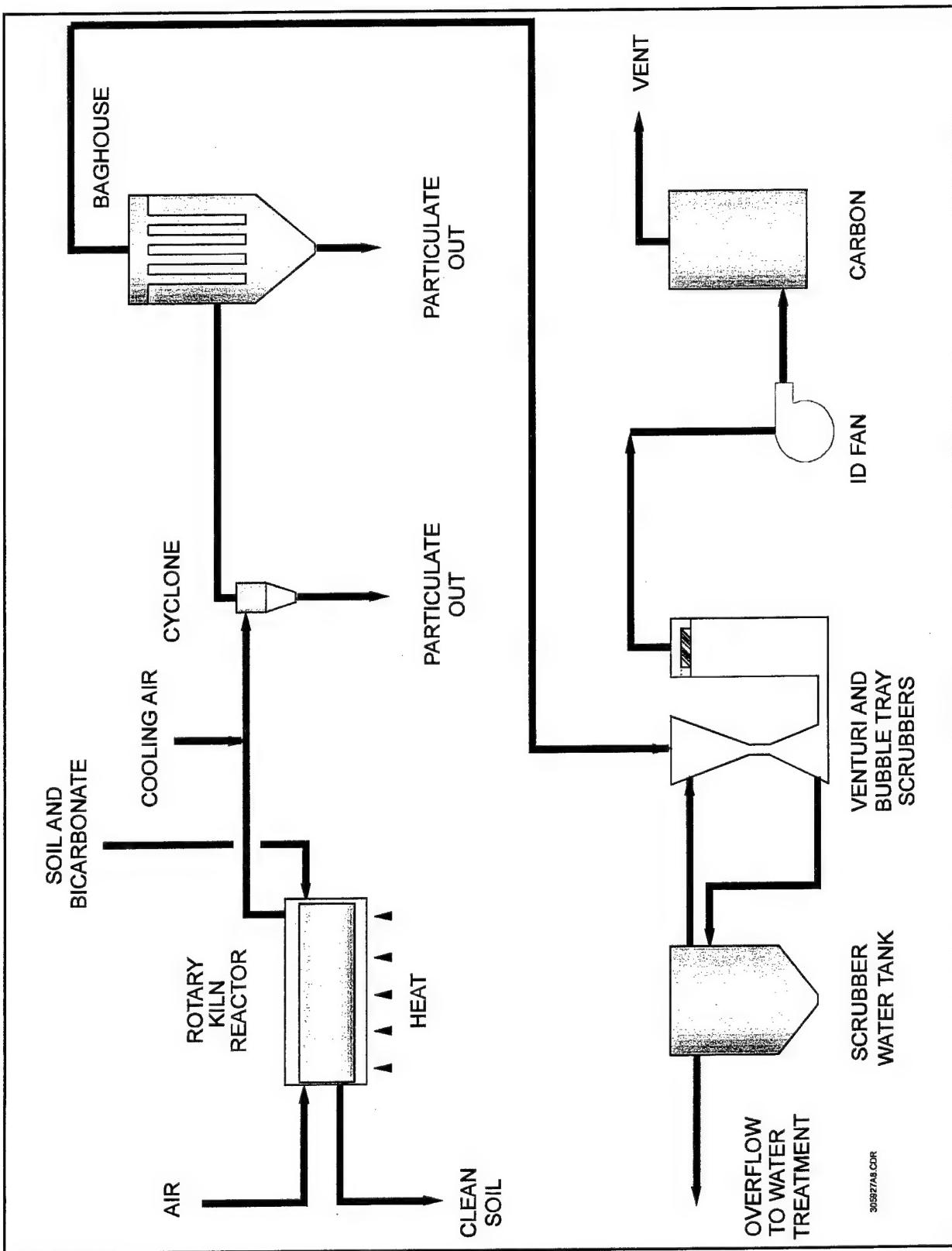
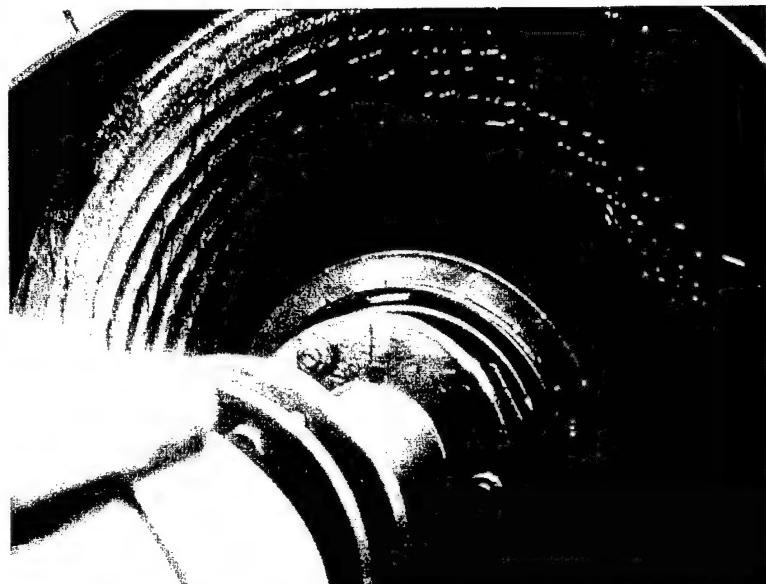


Figure 1-3
The Demonstration Plant Rotary Kiln Reactor and Air Pollution Control System

During the February 1994 hot run, oil resulting from ineffective APCS operation seeped out of the ID Fan along the drive shaft. This oil was heavier than water and contained about 1 percent PCB. This problem occurred again during another hot run in November. Once this oil appeared, it was produced at a fairly steady rate as long as the system operated. An examination of the ducts showed that the Fan inlet ducting was clean, but the outlet ducting was coated with this oil.



Oil Removed From the Off-Gas Stream Collecting on The ID Fan Housing During the Demonstration Run

These observations are best explained by the theory that the oil is being carried through the system as an aerosol. The cyclone, baghouse, and scrubber would have a very low removal efficiency on such an aerosol. When the aerosol reached the high speed fan, centrifugal forces in the fan slung the aerosol onto the fan housing and some of the submicron droplets agglomerated into droplets that were large enough to stay in the fan and build up in the housing. The large pressure drop that occurred in the throttling valve just before the fan could also cause agglomeration.

This aerosol theory is consistent with how the gas is created. In the RKR, PCBs and other organics in the soil are heated until they decompose and/or vaporize. The vapor leaves the soil and is swept into the off-gas stream. As the off-gas cools, the organic vapors condense. When dilute vapors condense, they condense into submicron particles.

Aerosol Removal. Submicron particles are difficult to remove from a gas stream. Some literature reports good removal efficiency of submicron dust particles using high energy water scrubbers. The oil generated by the RKR was not water soluble. It is doubtful that a hydrophobic material would be removed efficiently in a water scrubber. The Demonstration Plant did collect some of this heavy oil in the scrubber water, but clearly a significant amount of the oil passed through the scrubber. Oil scrubbers were suggested, but data could not be found on their effectiveness. The production system required equipment that would operate with a known efficiency.

WESPs and HEMEs will remove aerosols efficiently. This is well documented in literature [7]. In a WESP, particles are electrically charged and electrostatic forces are used to move the particle out of the gas stream.

The HEME depends on Brownian diffusion to remove submicron particles. The HEME is a thick, tightly-woven fabric that the gas passes through at a low velocity. Submicron particles continuously move around (Brownian Motion) because they are buffeted by vibrating gas molecules. As the gas moves through the HEME fabric, the particles collide and stick to the strands of fabric. As the organics build up on the fabric, they coalesce and gravity drain out of the fabric. In addition, particles larger than about 3 microns are captured by impaction.

Both the WESP and HEME have infinite turndown. As the gas flow decreases, their collection efficiency actually increases. This was an important consideration because gas flows had to be estimated during the design phase. The use of steam injection followed by condensation provided a much lower gas flow than using air as the sweep gas as was done in the demonstration phase. The gas flow using steam injection in the redesigned APCS was an estimate. Some collection equipment, like cyclones, would only operate efficiently over a small range of gas flows.

WESPs are generally not used to treat off-gas from a desorber because the organics levels can be high enough to form an explosive gas, and the high energy spark in the WESP could ignite that gas. As explained in Section 2.0, this problem was solved by inerting the system with steam. This meant, however, that the WESP had to be operated hot, so it was positioned as close as possible to the RKR. Gas leaving the WESP was around 200°F.

When the WESP off-gas was cooled, two factors contributed to additional organics being condensed. The cooling itself caused additional condensation, and the reduction in gas volume created by removing the steam also contributed to condensation. At a given temperature, the concentration of a particular organic in a gas that can remain in the vapor state is a constant (the saturation concentration). Removing the steam concentrated the organics in the remaining vapor and forced additional condensation. The gas passed through the HEME after it was chilled to remove this additional condensation.

Water Treatment Requirements. The baghouse in the demonstration system was effective at removing particulate while it operated. The design concept was good. Ideally, the particulate and

organics should be removed separately. During the demonstration runs, a heavy oil settled in the bottom of the Venturi Scrubber water recirculation tank and was collected by simply draining it off the bottom of the tank. This oil from the February 1994 hot run was 10.5 percent PCB. Oil collected during the November 1994 hot run was 16 percent PCB. These high concentration PCB residuals are ideal; the higher the concentration of residuals, the lower the volume of the residuals that must be disposed. The remaining water was relatively particulate free and could be treated by carbon to remove residual PCBs and other organics.

The redesigned system removed particulate and oil together in the water sprays in the WESP. This made the wastewater from the full-scale system much higher in suspended solids. A conventional water treatment plant was built to remove these suspended solids prior to carbon adsorption treatment.

Organics in the Off-Gas. Another important lesson learned in the demonstration system is that the off-gas contains a lot of organics that are not PCBs. The soil excavated on Guam contained naturally occurring organics, such as roots and decayed vegetation. When heated to the temperatures used in the RKR, many of these organics break down into lighter compounds, others come off and condense as heavy organics. The heavy oil collected in the scrubber water was 10 to 16 percent PCBs, so it was 84 to 90 percent non-PCB oil. The scrubber water during the hot runs developed a yellowish color and an odor, indicating that organics were carried in the water either as an emulsion or solution.

1.3.2 Rapid Start System

IT physically took over the system in December 1994. Plant operators arrived on Guam in January to begin construction on the production system. While equipment changes were being made to other parts of the plant, the new APSCS was being designed. By April 1995, the APSCS design was complete and the major APSCS equipment was on order. Equipment delivery was controlling the schedule. Specifically, the WESP, Chiller Condenser, boiler, and Primary Condenser would not be delivered until the Fall.

The "Rapid Start System" evolved as a result of this equipment delivery delay. Also, a Feed Preparation Building was to be constructed and the area where it was to be placed was contaminated. The soil in the Feed Preparation Building area was mostly low organic coral with low levels of contamination (50 to 100 ppm PCB). The soil under the Feed Preparation Building would have to be exca-

vated and replaced with purchased clean fill, or the soil could be excavated, treated in the BCDP, and backfilled. Because of the low level of PCB contamination and organics in the soil under the Feed Preparation Building it was decided that the soil would be treated in the partially constructed BCDP system. This saved the cost of purchasing backfill and allowed the crew to start site remediation while waiting for the last of the APCS equipment to arrive.

An engineering analysis indicated that the off-gas could be cleaned to an acceptable level by using the cyclone, Venturi Scrubber, HEME, and carbon. This analysis was based on the coral that would be processed. Not only was the coral low in PCBs, but it was also low in naturally occurring organics. This would put a light load on the APCS. The main concern was that, without the WESP and the reduced air flow benefit of the steam, the HEMEs would clog rapidly. The HEME element costs \$2,400 and required about five hours for two operators to change. If plugging occurred because of particulate instead of heavy organics, the problem was simpler and cheaper to solve. The HEME elements were protected by a prefilter bag that slipped over the element. This bag costs \$300 and could be replaced in a couple of hours.

The rapid start system also gave the operators a chance to start up and run a simpler system than the one that would ultimately be operated. This would provide training and allow debugging of the rapid start equipment before the remaining equipment was brought on line.

Figure 1-4 shows the rapid start system. The system treated about 650 tons of soil from mid-July to mid-September 1995. The Navy conducted a stack test shortly after start-up and found that the PCB Destruction Removal Efficiency (DRE) was between 5 and 6 nines and the dioxin furan Toxic Equivalent (TEQ) was 2.15 nanograms per cubic meter.

The processing rate during the rapid start was only 0.6 to 0.7 tph. This low production rate was caused by the absence of a Feed Preparation Building. The soil was generally too wet to feed rapidly.

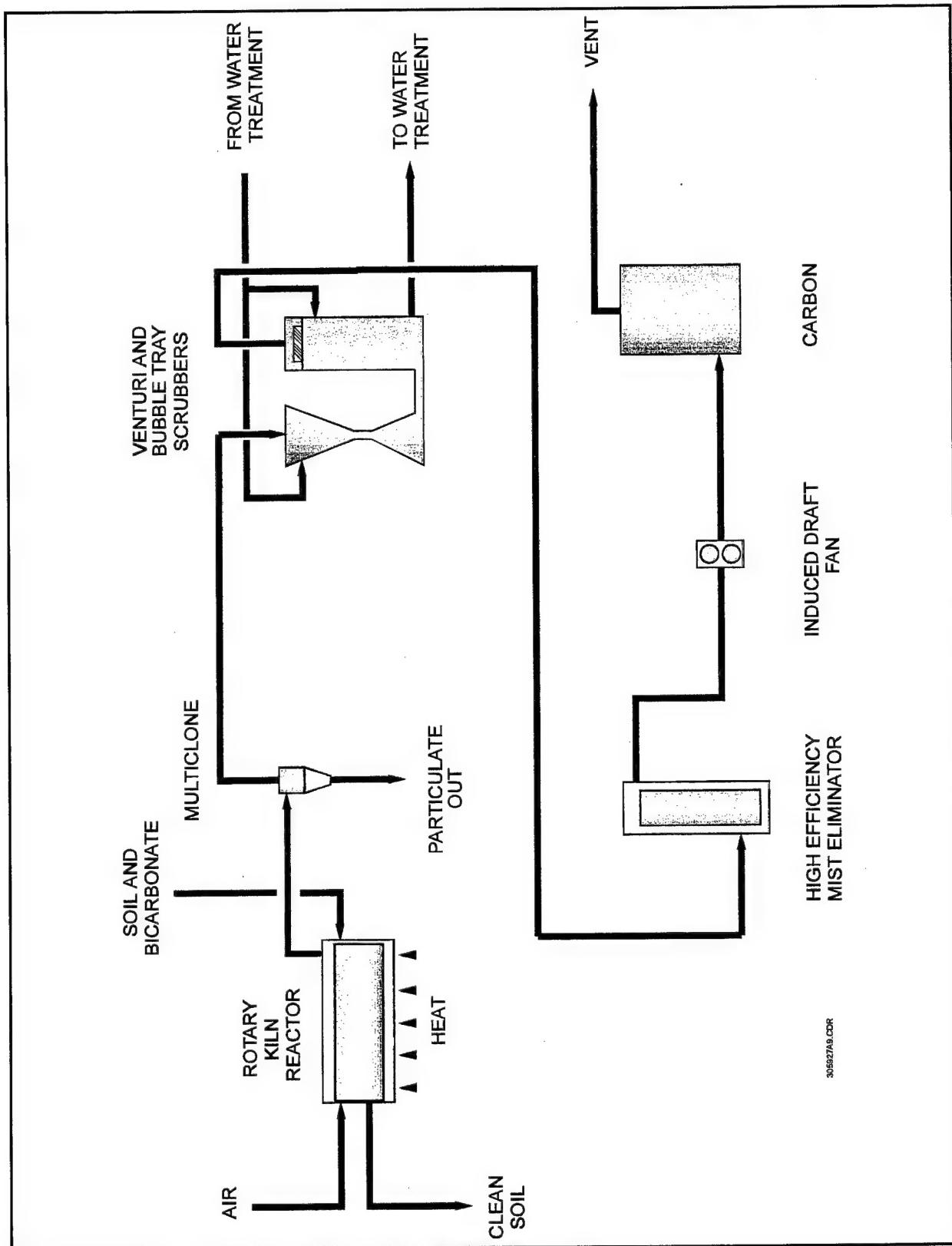


Figure 1-4
The BCDP Rapid Start System

1.3.3 Full Scale Remediation

When the rapid start runs ended, work began on the installation of the remaining APCS equipment. Between September and January 1996, the remaining equipment and the Feed Preparation Building was installed. The system operated for short periods in February and March as operating changes were made and additional construction occurred. During this start-up period, additional equipment modifications were made. At times, the rapid start configuration was used because of difficulties in starting up the WESP.

By April, the full-scale system was operating. Operation continued until the site was remediated. The Navy conducted a second stack test in early June showing that PCB DRE was 7 nines and the dioxin furan TEQ was 0.18 nanograms per cubic meter.

2.0 BCDP Production Plant Description

The physical plant is described in this section. Plant drawings found in Appendix A will be useful when reading this section.

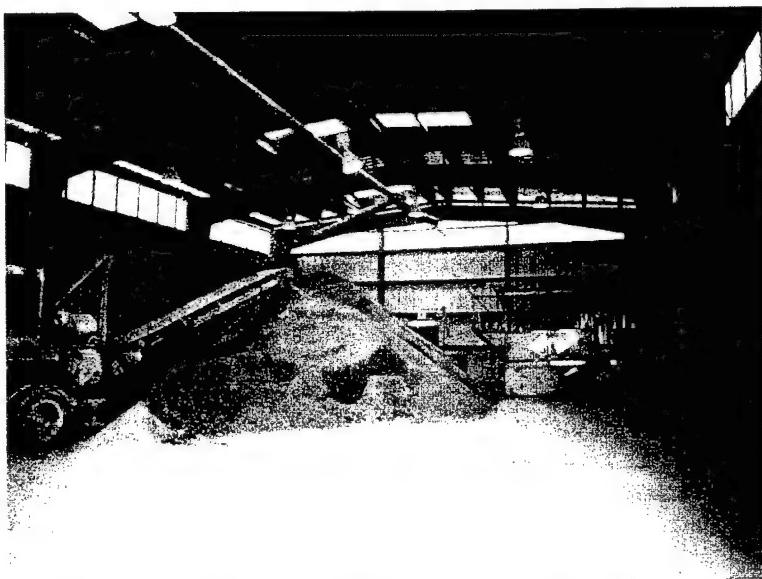
2.1 Plant Description

The plot plan can be found in Appendix A. The haul road for contaminated material runs south of the Feed Preparation Building. Excavated soil is stockpiled on the west side of the building. This provides a storage area and a place to dry wet soil. Wet soil is spread out over the area and tilled to dry in the sun if necessary. Soil that is dry enough to crush is carried through the 12-foot-by-13-foot high door on the southeast corner of the Feed Preparation Building and loaded onto the crusher. A concrete loading ramp was constructed near the crusher to allow the front-end loader to reach high enough to load the crusher.

Dry, crushed material is stockpiled inside the Feed Preparation Building. Surplus steel plate was available from the Navy and was used to set up barriers to reinforce the wall around the areas where the crushed material was stored. This allowed the material to be pushed up against the barriers and significantly increased the stockpile area within the building.

About 400 cubic yards of material could be stored in the building. The building was not used to dry the soil, but to keep dry soil out of the rain. From the stockpile area, the soil was loaded into the reactor feed conveyor hopper. This hopper holds about five tons of soil.

The Feed Preparation Building is the only Level C operating area in the plant. Two cameras located inside the building allowed a control room operator to view activities inside the building. One



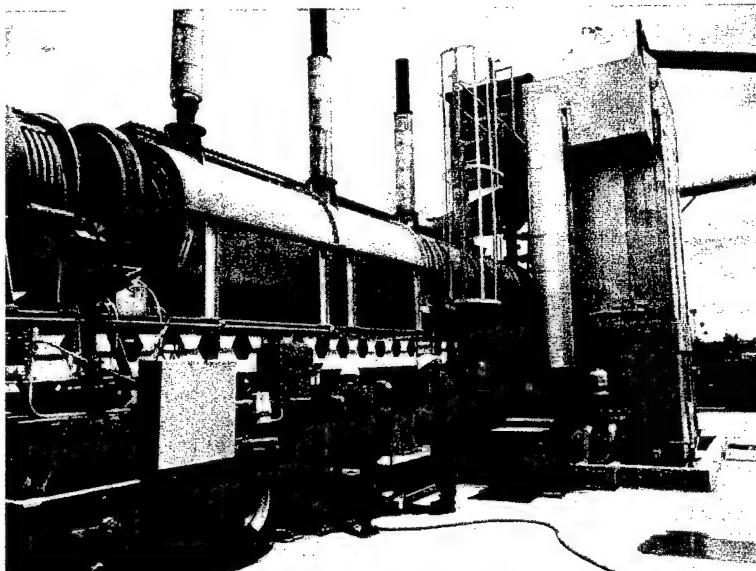
This Photo Shows the Interior of the Feed Preparation Building; the Crusher Discharge Conveyor and Soil Stockpile are Shown at the Left and Center of the Photo; the RKR Feed Hopper is in the Right Rear Corner of the Feed Preparation Building

camera located in the southeast corner of the building was capable of panning and zooming. This camera was used to monitor anyone working inside the building. Normally, two operators would be required inside the building for safety reasons. By using this camera, it was acceptable to have only one operator at a time dressed in Level C working inside the building. The second camera was located over the reactor feed conveyor hopper. With this camera, it was possible to see the hopper and the belt from the control room. This allowed the control room operator to judge the amount of material remaining in the hopper as well as spot a hopper pluggage that would stop material from being dropped onto the feed belt.

Normally, a Feed Preparation Building would have a ventilation system producing four to five air volume changes per hour. The air exhausting from the building would pass through a baghouse prior to discharge. This ventilation system is to protect the operators as well as prevent contaminated material from blowing out of the building. At this site, the soil was not dusty and personnel monitors worn by operators inside the building showed that OSHA PCB levels were not exceeded during work in the building. For that reason a building ventilation system was not installed.

The Navy had an active training center on the west side of the fence that marked the boundary of the excavated soil staging area. Air monitoring was performed at this fence line. A high volume air sampler was run daily to check for dust and a polyurethane foam (PUF) sampler was periodically run to check for PCBs. The PUF was operated less frequently because the on-site laboratory was not staffed to do daily PUF samples. As a backup, the dust samples collected by the high volume sampler were analyzed for PCBs. No PCB air excursions were ever recorded.

The reactor feed conveyor carries the soil from the feed conveyor hopper to the inlet valves of the RKR. Sodium bicarbonate was added directly to the soil traveling up the belt. The bicarbonate feeder



**The RKR as Viewed from the Soil Discharge End.
The Transformer Rectifier, Bus Duct, and WESP
are to the Right of the RKR**

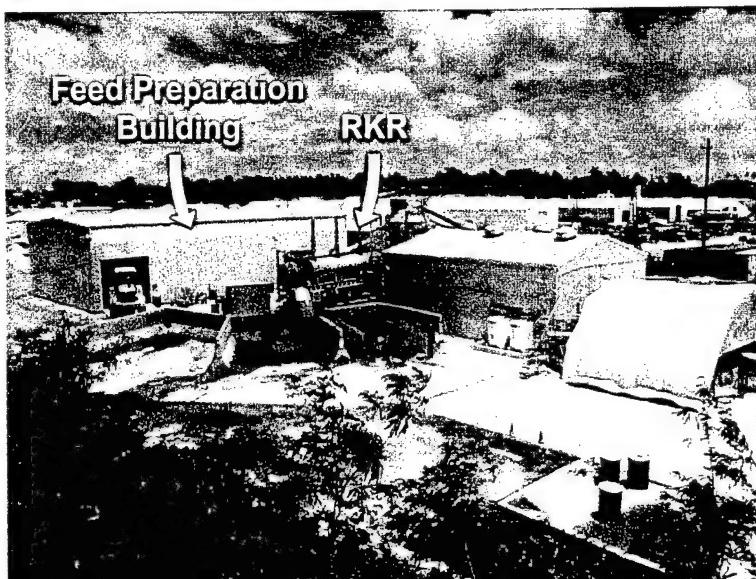
was housed in a building large enough to hold a one ton bicarbonate tote bag over the feed hopper. A screw conveyor carried the bicarbonate to the top of the reactor feed conveyor. The bicarbonate addition rate was measured by catching the bicarbonate discharge in a bucket over a time interval and weighing the amount caught. The bicarbonate and soil were mixed inside the RKR.

The RKR conveyed the soil from the feed end to the discharge end of the reactor while heating it to temperatures over 700°F. Soil discharged at the south end of the RKR onto the reactor product conveyor.

The reactor product conveyor carried the soil from the RKR to one of three reactor product or ash bins. Bins A and B were capable of holding about 24 tons of material and Bin C would hold almost 50 tons of reactor product. A sample of the product coming off the belt was taken every four hours while the system was operating. When a product bin was full and the conveyor was moved to the next bin, these samples were composited and crushed to facilitate analysis. The

composite sample was then analyzed to determine whether or not the material in the bin met the cleanup limit of two ppm maximum per PCB congener. The product bins were constructed out of concrete "K" barriers. These are the barriers that are normally used as road dividers or blockades during road construction. The 50-ton bin was used for weekend operation so the chemist could have a day off.

The ash was bone dry and very dusty. Water sprays were mounted at the discharge of the product conveyor to wet the material as it came off the belt. The water sprays were not completely effective because the first water to hit the hot dry product instantly boiled. This rapid evaporation and generation of steam blew dust off the belt. Enough water was added, however, to ensure that the



Plant Overview Showing the Three Reactor Product Storage Bins, Feed Preparation Building, and RKR

material in the ash bins was wet and no further dusting occurred after the material landed in the ash bin.

There was continual water runoff from the ash bins. Since the material in the bins was clean, the only contaminant carried by the water was suspended solids. The ash bins were sloped so that the water traveled into the ditch where a dam was built to contain the water while it evaporated and soaked into the soil. This area of the ditch where the water drained was remediated by the end of the project.

The control room was a 20-foot connex box located at the north end of the RKR. Temperatures and pressures throughout the system were monitored from the control room computer and some of the key operating parameters could be manipulated from the control room. Key control points were set to alarm if operating conditions exceeded limits. The alarm was both audible (with a buzzer) and visual. Red and yellow lights mounted on top of the diesel fuel storage tanks flashed to indicate an RKR burner problem (yellow), or a problem elsewhere in the BCDP (red).

The boiler that provided steam for the RKR and WESP was placed just west of the control room. A large shed north of the boiler was used to store sample jars and samples, as well as to provide a work area for minor maintenance. The shed contained a refrigerator for sample storage and a decontamination boot wash area. Protective clothing was also stored here. A similar shed was provided just west of ash Bin C. Operators working in the Feed Preparation Building changed from Level D to Level C clothing in this shed.



The Boiler Used to Provide Steam to the RKR and WESP

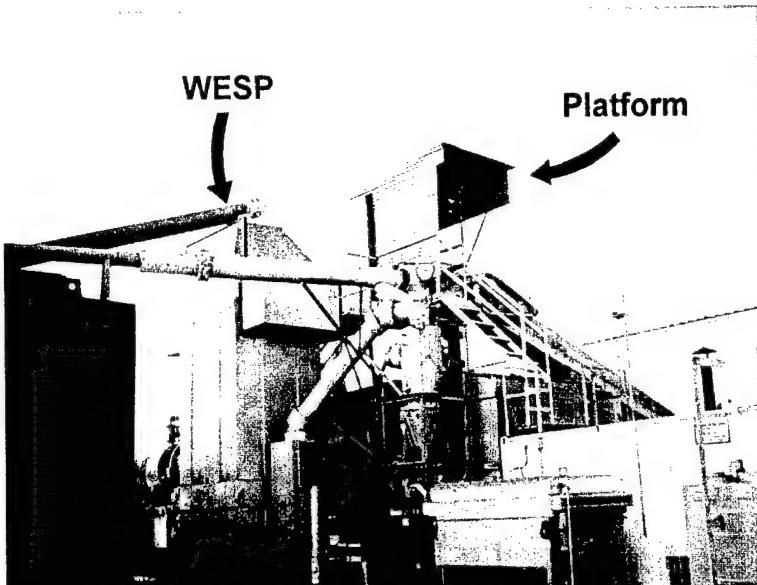
Off-gas from the RKR traveled through the cyclone, where dust was removed, and then into a quench section at the inlet of the WESP. In the quench, gas was cooled to slightly below 212°F and

water saturated. The water saturated gas traveled through the WESP where particulate and condensed organic aerosols were removed.

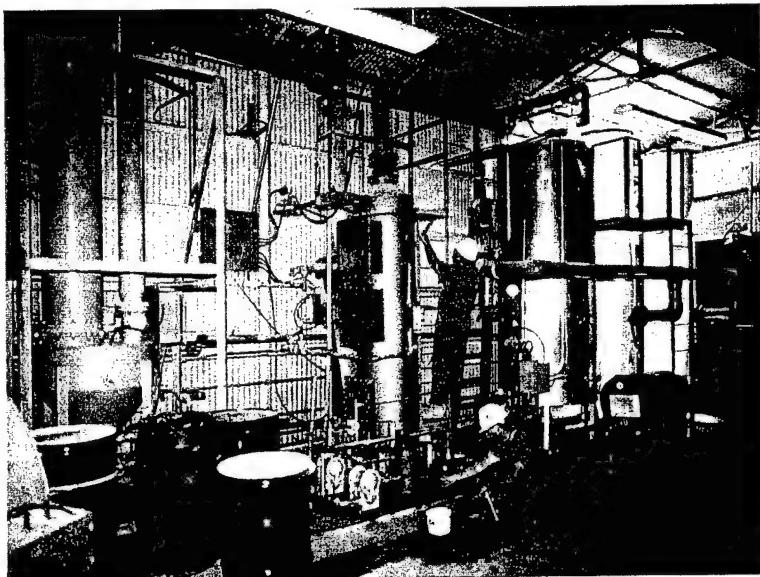
From the WESP, the gas was ducted to the Primary Condenser in the air pollution control (APC) building. Almost all the steam was condensed in the Primary Condenser. The gas exited the Primary Condenser and traveled through the Venturi Scrubber. The Scrubber was not operated during the full-scale system, but gas traveled through it because that is the way the piping was routed; the Venturi Scrubber had been used earlier during the rapid start, and was left in place to spare the labor cost of removing it.

From the Venturi Scrubber, the gas went through the Chiller Condenser where it was cooled down to 40 to 50°F. From the Chiller Condenser, the gas passed through one of two parallel HEMEs. These HEMEs removed virtually all of any remaining particulate and condensed organics.

From the HEME, the gas exited the APC building and passed into the ID Fan. This Fan provided the driving force for pulling the gas



The Multiclon and WESP at the Soil Feed End of the RKR;
Note the Covered Platform Built Above the Reactor Feed
Valves to Allow Easy Access for Removing Plugs

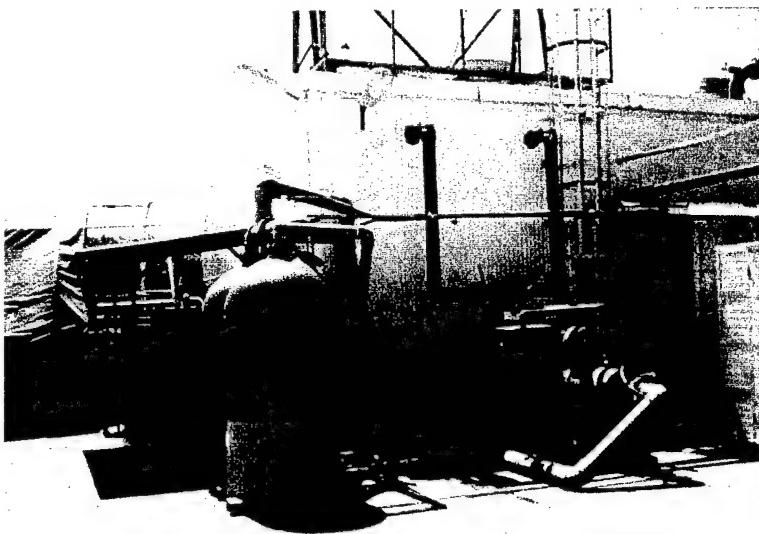


APCS Equipment Inside the APC Building;
From Left to Right, the Photo Shows the Primary
Condenser, Venturi and Bubble Tray Scrubbers,
Chiller Condenser, and HEMEs;
Note the Open Roof Hatch Over the HEMEs
Through Which the HEME Elements are Removed

from the reactor to this point. From the ID Fan, the gas was forced through two air carbon adsorption units in series and then exited the vent pipe to the atmosphere.

The Cooling Tower and Chiller Refrigeration Building are located just north of the APC building. The Cooling Tower provided water to the Primary Condenser and the Chiller Refrigeration Building. The Chiller Refrigeration Building housed the compressor and heat exchangers that produced a cold ethylene glycol/water solution for the Chiller Condenser.

Condensate from the Primary Condenser and Chiller Condenser were pumped to the Surge Tank at the beginning of the water treatment plant. The Surge Tank is set on the east side of the APC building. All other contaminated water, including water from the decontamination pad, washdown water, and potentially contaminated storm water, were also pumped to the Surge Tank. The Surge Tank was covered with a steel frame and canvas building to exclude rain water.



The ID Fan is Shown on the Right, Discharging Into The Two Carbon Beds Shown on the Left; Fan Suction Piping Coming from the HEMEs Exits Through the Building Wall

From the Surge Tank, the water was pumped back into the APC building to a flocculation system where it was rapid mixed with polymer and then introduced into the flocculation tank. The flocculated water overflowed from the flock tank to the clarifier. The clarifier was set in the Surge Tank to provide secondary containment for the clarifier.

Clarified water overflowed back into the APC building to the clarified water tank. This tank provided process water for the plant. Water was recirculated from the clarified water tank to the WESP quench. A smaller flow was taken from the clarified water tank and passed through bag filters, Oleophilic Media drums to absorb oils, and then through water carbon treatment to remove

soluble organics and residual PCBs. Oleophilic Media is a mixture of clay and anthracite that absorbs oil. This material will not only remove free oil, it will break oil out of emulsions.

This water then discharged into the treated water tank. Make-up water was also added to the treated water tank as needed. This water was used to spray the reactor product conveyor belt and cool the reactor product.

2.2 Solids Handling Equipment

The solids handling equipment consisted of the crusher, reactor feed conveyor, bicarbonate feed system, and the RKR.

2.2.1 Rock Crusher

The soil was crushed in a crushing plant to a nominal 1.5-inch size. The crusher is rated for up to 20 tph. Since the RKR runs at about two tph maximum, crushing was done in batches as required. Crushing was necessary to improve the heat exchange within the RKR and to facilitate processing the material through the equipment. If particles were too large, they would not have enough residence time to heat thoroughly in the RKR.

Feed to the crusher was through a 12-inch hydraulically operated grizzly located on top of the crusher feed hopper. Originally, the grizzly was 6 inches, and was modified to have 12-inch openings. This grizzly removed large boulders and debris that might otherwise enter and damage or plug the crusher. Rotating, hardened, manganese steel hammers crushed the material. Crushed soil fell through openings in the discharge chute to the discharge conveyor which carried the material from the crusher to the stockpile. The crusher was powered by a diesel engine. Diesel exhaust was piped to the outside of the Feed Preparation Building.

The crusher was built as an asphalt crusher. Although there were some concerns about its durability at the beginning of the project, it worked as designed without excessive maintenance. If there was excessive moisture in the soil, it would pack up inside the crusher and plug, so crushing operations were only conducted on soil that was dry enough to process. Although the intent was to crush everything down to a 1.5-inch size, there were two and three inch rocks that passed through the crusher. Fortunately, this larger material did not cause any major materials handling problem for the rest of the equipment within the treatment train.

2.2.2 Reactor Feed Conveyor

The reactor feed conveyor moved the material from the Feed Preparation Building to the RKR inlet, located about 15 feet above the ground. The reactor feed conveyor hopper held about five tons of soil and was loaded with a front-end loader as necessary.

Material from the hopper fell on a short, horizontal conveyor belt. The speed of this conveyor was controlled automatically to deliver the set point feed rate to the 60 foot long main conveyor. The main conveyor belt speed was not adjustable.

The feed conveyor had a weigh belt section that recorded the amount of material passing along the belt. This was used to keep track of production.

The reactor feed conveyor operated well as long as the feed was relatively dry. If the feed material was too wet, it would bridge and fail to flow into the hopper and had to be manually freed.

2.2.3 Bicarbonate Feed System

Sodium bicarbonate was received at the site in one-ton tote bags. These were taken as needed to the bicarbonate feed building where they were hung by a hoist above the bicarbonate feed hopper. The bags were dumped into the hopper as needed to keep material in the hopper. A screw conveyor on a variable speed drive conveyed the bicarbonate from the feed building to the reactor feed conveyor. The bicarbonate flow rate was calibrated by using a bucket and stop-watch and catching material as it fell out of the screw conveyor onto the belt.

Sodium bicarbonate is hygroscopic and the humid air on Guam caused the material to cake up in the tote bags. Problems were experienced with the screw conveyor which would occasionally jam and even break.

2.2.4 Rotary Kiln Reactor

The RKR is a calciner with a nameplate rating of two tph. The purpose of the RKR is to heat the soil and bicarbonate to a high enough temperature (about 700°F) and a long enough residence time (approximately one hour) to decompose and drive off PCBs and create a soil product that would pass the two ppm per PCB congener treatment standard.

The interior of the reactor was a rotating carbon steel shell 30 feet long and 3 feet in diameter. Soil entered at one end of this shell and traveled through the rotating shell to the soil discharge end of the reactor while being heated. The furnace around the shell was a stationary refractory with 14 diesel fuel burners firing tangentially around the shell. The burners are spark ignited using a propane pilot gas and are divided into four separate zones along the shell corresponding to the four stacks coming out of the top of the reactor. These four zones each had an individual thermocouple going through the side of the refractory to measure the gas temperature between the refractory and the shell. Since the reactor shell is carbon steel, it cannot be heated much above 1,000°F, and these thermocouples indicate the maximum shell temperature while the reactor is running. Combined, the burners were rated at 7 million British thermal units (Btu) per hour.

The reactor shell was normally driven by an electric motor. A propane motor was used if the electric drive failed. At operating temperature, the steel shell was weak, and if rotation stopped while the shell was at temperature, it would sag.

Soil enters the reactor through two 10-inch knife gate valves that provide a seal at the entry point. Only one valve is open at a time. In the cycle, the top knife gate opens and soil falls into the feed pipe and settles on the bottom knife gate valve. After about 20 seconds, the top knife gate closes and the bottom knife gate opens, allowing the soil to flow down into the reactor. Soil feed from the feed conveyor is continuous and while the top knife gate is closed, soil accumulates on top of the valve. Two knife gates at the soil discharge end operate in the same fashion.

The soil feed knife gates would plug if the soil was too wet because the soil would pack as it fell on a closed valve. When the valve opened, the soil would bridge and not drop through the open valve. An operator had to climb up to the valve and manually unblock the jam. A platform with access ladders was built around the feed valve to allow easy access to the jam point.

A seal is also required where the rotating shell contacts the stationary feed and discharge breaches of the reactor. The seal at this point is complicated by the fact that the shell actually increases in length by an inch or two when it heats up due to thermal expansion. As the shell expands, it does so against a spring loaded bellows which moves back as the shell presses into it. A rotating flange on the shell makes direct contact with a stationary flange on the end of the bellows. To minimize wear, high temperature grease is pressure injected between these two flanges periodically as the kiln operates.

The rate at which soil is conveyed down the shell is determined by kiln rotation and slope. The kiln typically rotated between one and two rpm and was sloped about three degrees downward from the feed end to the discharge end. The slope of the kiln was difficult to change because of piping that had been attached to the unit. The rotation rate was used to control soil residence time inside the kiln. Horizontal flights extending out from the kiln shell inside wall about one inch provided some lift and agitation to the material in the shell.

A sweep gas is necessary to remove the gaseous contaminants driven off the soil in the kiln. During the demonstration runs, this sweep gas was diesel exhaust which was piped from the exhaust stack closest to the soil discharge end of the reactor into the shell itself. During the production runs, this diesel exhaust sweep gas was replaced by steam which was injected into the soil discharge end of the reactor through a flow control valve. This control valve allowed the sweep gas flow rate to be set independently of the vacuum inside the kiln.

During the demonstration runs, the soil would drop out into the feed breach section of the kiln and accumulate. This accumulation was a combination of feed soil which spilled back over the dam on the rotating shell at high feed rates and fines which fell out as the exhaust gas was pulled out of the feed end of the kiln. This material would accumulate and pack up around the rotating shell, which extended into the stationary breach, and eventually built up enough friction to hinder the rotation of the shell. The breech drop is shown in Figure 2-1.

A 10-inch knife gate and chute were installed at the bottom of the feed breach section of the kiln to drop this material out and keep the breach area clean. A vibrator was also mounted on the side of the breach. The material dropped into a 55-gallon drum through a bellows pipe. The knife gate valve was normally open and was only closed to isolate the kiln while the drum of collected material was changed out with an empty drum. The material collected at this point was higher in feed soil than in fines. These drums were carried back to the Feed Preparation Building where the collected material was recycled to the kiln.

2.3 Air Pollution Control System Design Basis

The APCS was redesigned between the demonstration and full-scale runs. The APC equipment that was used during the demonstration run was not used during the full-scale production runs. The steam injection system had never been used before and the amount of air infiltration that would occur throughout the system was unknown during the design of the new APC equipment. Estimates of

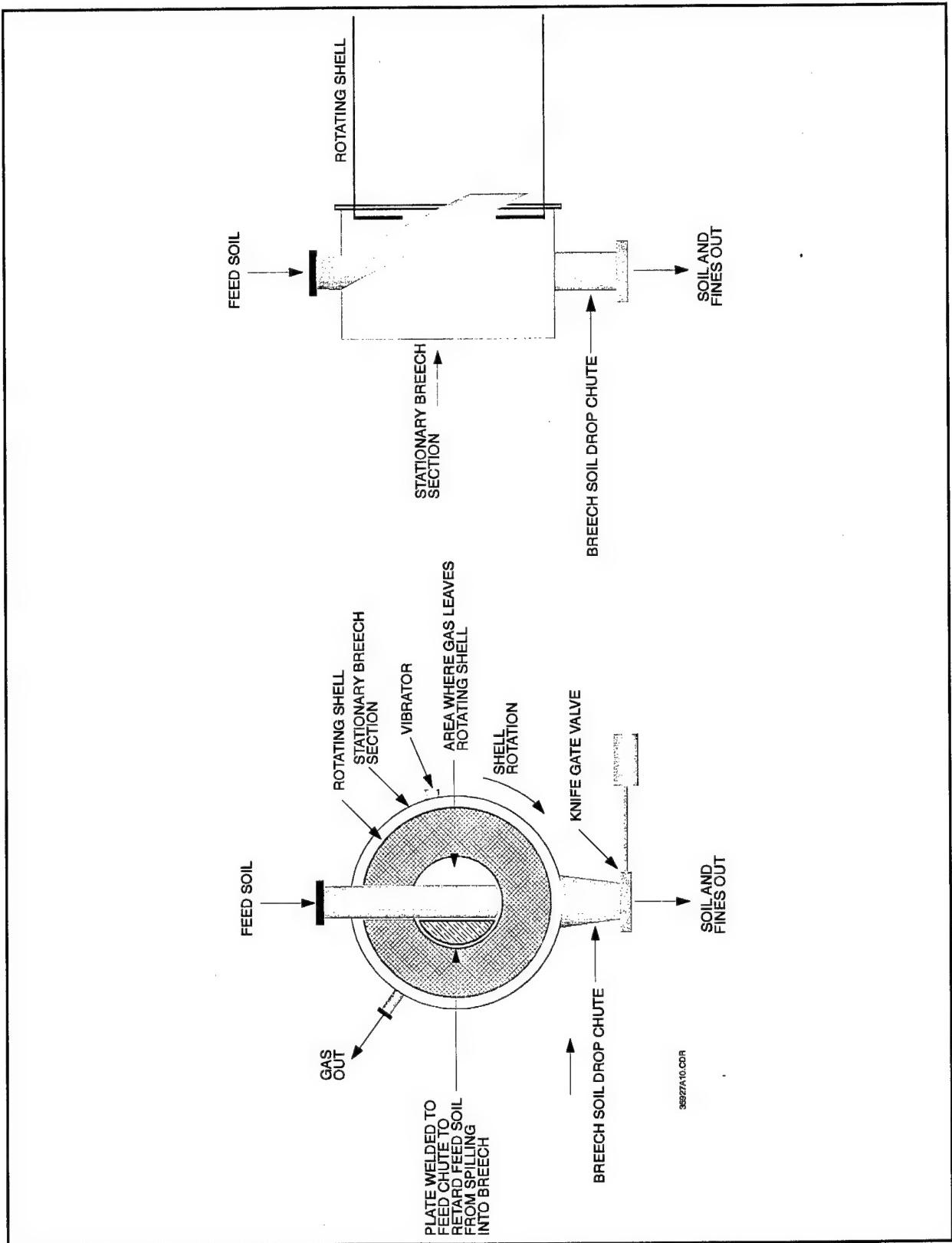


Figure 2-1
RKR Breach Fines Drop

infiltrated air turned out to be very conservative and actual gas flow rates were much lower than had been projected. This should be kept in mind when comparing the actual operating conditions of the APC equipment with the size of the equipment itself.

The design of the APCS involved several new concepts. The objective was to create a system that had state-of-the-art contaminant removal efficiency and would be environmentally safe to operate over the extended remediation time period.

Prior to the BCDP system, incinerators set the standard for removal efficiency for thermally processing contaminated soil. The BCDP's emissions are lower than the levels allowed by hazardous waste incinerator air emission standards for PCBs, dioxins and furans, metals, and particulates.

Incinerators are subject to upset conditions if the organics being driven off the soil are inadvertently ignited. This sometimes happens and creates a positive pressure in the unit that can cause contaminants to leak out. In the BCDP, the oxygen level was kept sufficiently low throughout the entire system that ignition could not occur.

The combined benefits of high removal efficiency and inert (nonflammable) conditions in the RKR and APCS are achieved by the use of steam. Steam is used in the hot end of the system as a carrier for the contaminants and to displace oxygen. The steam condenses as the gas is cooled. With the steam removed, the remaining contaminants are concentrated into a low volume of dry gases. This low gas flow concentrates the high molecular weight contaminants (PCBs) and allows them to further condense and be economically removed and disposed.

2.3.1 Organics Removal Mechanism

The design of the APCS is based on organics removal by two independent pathways: condensation and water solubility. The exact composition and concentrations of the organics in the off-gas vary depending on the feed soil composition, the operating temperatures in the kiln, and the amount of oxygen (i.e., air) that infiltrates into the kiln. Based on the available literature as well as our experience on Guam, when naturally occurring organics are heated to the point of decomposition (pyrolysis), a wide range of organic compounds will form. The analysis is therefore performed by examining the fate of a range of organics that are similar to those that would be expected in the off-gas stream.

Organics in the off-gas of the BCDP system can be grouped as follows:

1. Volatile, nonsoluble gases (such as methane)
2. Volatile, soluble gases (such as acetone)
3. Semivolatile, soluble compounds (such as phenol)
4. Semivolatile, nonsoluble compounds (such as anthracene).

PCBs fall into the fourth category; removal of these compounds is the main goal of the APCS.

Compounds in the first category can only be captured, if at all, by the Carbon Adsorber, and are not considered further in this evaluation. The other three classes of compounds will be analyzed using the compounds listed above as examples. Although phenol and anthracene are both classed as semivolatiles, the phenol is much more volatile than the anthracene, and the analysis evaluates the effect of volatility on capture.

Organics leave the RKR as a vapor and are continuously cooled from the time they leave the reactor until they contact the ID Fan. Some organic vapors will reach their saturation point and condense to aerosol liquids as they cool down. These condensed organics can be removed by the WESP, Primary Condenser, and HEME. The calculations assume that the organics start condensing at their dew point (i.e., supersaturation does not occur) and, once condensed, they are available for removal in this equipment.

The other removal mechanism is by the organics dissolving into the condensate generated in the Primary Condenser. Water soluble organic vapors as well as liquids can be removed by solubilization into the condensate.

The specific organics that are evaluated are intended to be representative of the organics that will be found in the off-gas. Thus, even though phenol and acetone are water soluble and will be removed in the scrubber water, their removal by condensation only is discussed. In this context, these compounds are intended to represent non-water soluble compounds with similar molecular weights and vapor pressures.

Table 2-1 provides some information about the compounds to be evaluated. They have molecular weights ranging from 58 to 352, melting points from -140°F to over 420°F, and boiling points between 133°F and 750°F.

Table 2-1
Example Organics to be Evaluated

Compound	Molecular Weight	°F	
		Melting Point	Boiling Point
Acetone	58	-140	133
Phenol	94	109	358
Naphthalene	128	178	425
Anthracene	178	420	644
Aroclor 1260	352		750

Table 2-2 shows the vapor pressure of the compounds.

Table 2-2
Vapor Pressure, psia, at Temperature, °F

Pounds Per Square Inch Absolute (psia)	Acetone	Phenol	Anthracene	Naphthalene	Aroclor 1260
1.74E-06					68
0.019	-74	104	293	127	
0.097	-40	144	343	166	
0.193	-23	164	368	186	
0.387	-5	186	395	215	
0.773	15	212	423	247	
1.160	28	227	449	266	
1.934	45	250	482	294	
3.867	72	282	534	334	
7.735	103	320	590	380	
14.696	133	359	647	424	752

To allow the calculation of vapor pressure at other temperatures, a linear regression of natural logarithm (Ln) of the vapor pressure (VP) versus the reciprocal of the temperature (T), degrees Kelvin, is performed. The regression is to find the constants in the equation $\ln(VP) = a/T + b$. The equations to predict the vapor pressure in pounds per square inch absolute (psia) based on temperature in °F are shown below:

- Acetone $p = \exp(-7245.33*(1/(T+460)) + 14.95)$
- Phenol $p = \exp(-11945.1*(1/(T+460)) + 17.42)$
- Naphthalene $p = \exp(-11155.8*(1/(T+460)) + 15.43)$
- Anthracene $p = \exp(-15291.8*(1/(T+460)) + 16.75)$
- Aroclor 1260 $p = \exp(-14921.6*(1/(T+460)) + 15.00)$

The vapor pressures together with the temperature, flow rate, and composition of the gas at the removal points in the APCS will allow a prediction of the removal that occurs at the points in question. The conditions at the removal points are shown in Table 2-3.

**Table 2-3
Conditions at Removal Points**

Location	Temperature (°F)	Weight Fraction Water	Mole Fraction Water	Total Gas Flow (pounds/hour)
HEME	40	0.005	0.00803	131
Condenser	100	0.0663	0.10266	140
WESP	200	0.754	0.83160	900

Two removal mechanisms are evaluated. Condensed vapors existing as micron and submicron aerosols can be removed as a liquid in the WESP and HEME. The other removal method is by dissolving in water. When water soluble organic vapor comes in contact with water it will move to reach an equilibrium with the water. The portion that dissolves in the water will be removed in the water stream. These removal mechanisms will be considered separately.

2.3.1.1 Removal by Condensation

This model assumes that 100 percent of the condensed material at the WESP and HEME will be removed. Some removal of organic droplets will occur in the Primary Condenser, but most of the removal here will be due to water soluble organics solubilizing into water.

This model considers each compound independently. In the actual system, many organic compounds are present together. The interaction of these different compounds should increase the rate of removal. Uncondensed organic vapors are soluble in the condensed organics. In addition, the presence of other organics may act to lower the dew point of individual organics. Actually quantifying these effects is difficult, but they will act to make the actual removal better than that which is predicted by this model.

The other assumption is that the organics condense at their dew point and do not supersaturate. If supersaturation occurs, the actual removal will be less than predicted.

The calculation method will be illustrated by using acetone at the HEME as an example. Remember that although acetone is water soluble, in this example it is used to represent removal by condensation only. The HEME operates at 40°F, and the vapor pressure at that temperature is calculated from the regression equation.

$$\begin{aligned}\text{Vapor Pressure} &= \exp(-7245.33*(1/(40+460)) + 14.9496) \\ &= 1.583 \text{ psia}\end{aligned}$$

The mole fraction of acetone in the vapor is the ratio of the vapor pressure of the acetone to the total system pressure. System pressure will be taken as atmospheric. The mole fraction of a gas is also the same as the volume fraction. At 40°F, the volume fraction of acetone in the vapor is:

$$1.583/14.696 = 0.108$$

To calculate the weight fraction and the total pounds per hour of the acetone in the vapor, the gas is assumed to consist of water vapor, acetone, and air.

From a psychometric chart or vapor pressure table, the weight fraction of water in saturated air at 40 degrees is 0.005.

Basis: 100 pounds of gas:

$$\begin{aligned}\text{Pounds of water} &= 0.5 \\ \text{Pounds of air} &= 100 - 0.5 = 99.5\end{aligned}$$

$$\begin{aligned}\text{Moles of water} &= 0.5/18 = 0.0278 \\ \text{Moles of air} &= 99.5/29 = 3.4310\end{aligned}$$

$$\text{Mole fraction of water} = 0.0278/(0.0278+3.4310) = 0.00804$$

The molecular weight of water is 18, air is 29, and acetone is 58. The weight fraction of acetone in the vapor at the HEME is calculated as follows:

Basis: 100 moles

$$100 * 0.1077 = 10.77 \text{ moles of acetone}$$

$$100 - 10.77 = 89.23 \text{ moles of water and air}$$

$$89.23 * (1 - 0.00804) = 88.5125908 \text{ moles of air}$$

$$89.23 * 0.00804 = 0.7174092 \text{ moles of water}$$

$$\text{Pounds of acetone} = 10.77 * 58 = 625 \text{ pounds}$$

$$\text{Pounds of gas} = 0.717 * 18 + 88.513 * 29 = 2,580 \text{ pounds}$$

Total weight of 100 moles of gas at the HEME is $2580 + 625 = 3205$ pounds. The weight fraction of acetone in the saturated gas at the HEME is thus:

$$625/3205 = 0.195$$

If the gas leaving the HEME is saturated, the amount of acetone that can be carried in this stream is:

$$131 * 0.195 = 25.5 \text{ pounds/hour}$$

The results are summarized in Table 2-4.

Table 2-4 Analysis of Acetone in the Gas Stream					
°F	Vapor Pressure (psia)	Volume Fraction in Vapor	Weight Fraction in Vapor	Gas Flow (pounds/hour)	Acetone (pounds/hour)
40	1.583	0.108	0.195	131	25.5
100	7.475	0.509	0.683	140	95.6
200	53.086			900	900

As shown in Table 2-4, 25.5 pounds per hour of acetone will be carried past the HEME if the gas is saturated with acetone. The removal of acetone by condensation at this point will occur only if the mass flow of acetone exceeds 25.5 pounds per hour. At the Primary Condenser, 95.6 pounds per

hour of acetone can be carried by the saturated vapor. The WESP at 200 degrees is above the boiling point of acetone, and removal by condensation will not occur.

Table 2-5 shows the results of the same calculation procedure for the organic compounds being considered. Table 2-5 shows the pounds per hour of each compound that can be carried past the removal point as a saturated vapor.

Table 2-5 Summary of the Saturated Flow Rate of Target Compounds at Different Temperatures					
°F	Acetone (pounds/hour)	Phenol (pounds/hour)	Naphthalene (pounds/hour)	Anthracene (pounds/hour)	Aroclor 1260 (pounds/hour)
40	25.5	0.045	0.060	5.4E-05	3.9E-05
100	95.6	0.64	0.49	1.6E-03	1.06E-3
200	900	81	0.90	0.54	0.54

As an example, assume that the plant is running at 3,000 pounds per hour of soil. If the soil contains 1,000 ppm PCB, then the amount of PCBs that can be driven off the soil is:

$$3,000 * 1,000/1,000,000 = 3 \text{ pounds/hour}$$

At the WESP, 0.54 pounds per hour of PCBs can pass in the saturated gas. The amount that would be removed at the WESP would be:

$$3 - 0.54 = 2.46 \text{ pounds/hour}$$

Thus, 82 percent of the PCBs would be removed at the WESP. Table 2-6 shows the removal efficiency at the WESP for different concentrations of PCBs in the soil.

Table 2-6
Removal Efficiency at the WESP as a Function of the PCB Concentration in the Soil

Soil (ppm PCB)	Total pounds/hour, PCB	Pounds/Hour Passing WESP	Pounds/Hour Removed in WESP	Percent Removal
100	0.30	0.54	0.0	0.0
1,000	3	0.54	2.46	82
1,500	4.5	0.54	3.96	88
2,000	6	0.54	5.46	91
3,000	9	0.54	8.46	94
4,000	12	0.54	11.46	96
5,000	15	0.54	14.46	96
6,000	18	0.54	17.46	97

As Table 2-6 shows, the WESP will not remove any PCBs if the concentration in the soil is low, such as 100 ppm or less. As the level of PCBs increases, the WESP becomes more important in removing the PCBs. This same trend will exist for other low volatility organics.

Table 2-5 shows that only 0.000039 pounds per hour of PCB can pass the HEME in the saturated gas. Using the example of 3,000 pounds per hour of soil feed to the plant, the removal efficiency at the HEME as a function of PCB concentration in the soil is shown in Table 2-7.

Table 2-7
Removal Efficiency at the HEME as a Function of the PCB Concentration in the Soil

Soil (ppm PCB)	Total Pounds/Hour PCB	Pounds/Hour Passing HEME	Pounds/Hour Removed in HEME	Percent Removal
500	1.5	0.000039	1.49996	99.9974
1,000	3.0	0.000039	2.99996	99.9987
1,500	4.5	0.000039	4.49996	99.9991
2,000	6.0	0.000039	5.99996	99.9994
3,000	9.0	0.000039	8.99996	99.9996
4,000	12.0	0.000039	11.99996	99.9997
5,000	15.0	0.000039	14.99996	99.9997
6,000	18.0	0.000039	17.99996	99.9998

The HEME will achieve 4 to 5 nines removal of PCBs. As the feed becomes more contaminated, the removal efficiency increases. Of course, with the WESP in the system before the HEME, the HEME will see at most 0.54 pounds per hour of PCBs. The overall removal, however, with or without the WESP, will be the numbers shown in Table 2-7.

In summary, the WESP will take out high concentrations of low volatile organics as well as almost all the dust in the off-gas. Because of the high temperature in the WESP, the condensed organics will have a relatively high boiling point. These are exactly the organics that would tend to plug the HEME. The WESP operates at a much higher temperature than the HEME and is continuously flushed with water. It is thus better able to handle viscous organics as well as dust. Handling high concentrations of heavy organics at the higher temperatures in the WESP also has the advantage that the viscosity of organics decreases with temperature. The organics will be more flowable at the WESP temperatures than at the HEME temperatures.

The HEME depends on the organics being flowable and able to drain down through the filter pad. If organics that are too viscous to flow at 40°F are trapped by the HEME, the HEME element will plug and have to be replaced. In general, high viscosity organics tend to have low volatility. If any dust flows into the HEME, it will be trapped in the fabric and will not drain. The WESP thus acts to protect the HEME by removing high concentrations of viscous organics and solid particulate.

Organics are generally soluble in other organics. The more volatile (less viscous) organics that are preferentially condensed in the HEME should act as a carrier for the heavier organics that accumulate there, thus promoting drainage from the unit.

The air capture system was designed to achieve 4 to 5 nines removal at the HEME. After the HEME, the gas passes through carbon for a final polish. Because of the very low levels of PCBs in the gas entering the carbon, very little carbon is saturated with PCBs, providing the carbon with a long service life.

The HEME provides a barrier to prevent PCBs from escaping if the WESP should lose power. The system will operate at almost the same efficiency without the WESP. HEMEs will plug and have to be replaced if the WESP is not operating, but operating experience on Guam showed that the life of a HEME is measured in weeks without the WESP. Two HEMEs were operated in parallel. When

the pressure drop became excessive in one HEME, the gas was manually valved to the second HEME and the plugged HEME was replaced.

2.3.1.2 Removal by Dissolving in Water

Many organic compounds, especially naturally occurring compounds, are water soluble. Phenol and acetone are two examples.

The phenol and acetone will try to reach an equilibrium in the Primary Condenser water. As before, these compounds will be used as examples to allow a generalization about the removal of soluble compounds in the APCS. Both the quench and WESP are flooded with water, but the Primary Condenser is the lowest temperature point where the gas contacts water, thus Primary Condenser operating conditions will set the removal efficiency.

Phenol will be used as an example. Phenol is soluble in water up to about 8 percent. When phenol is dissolved in water, it will exert an equilibrium vapor pressure that is equal to the mole fraction of phenol in the water times the vapor pressure of the phenol.

Sample Calculation:

Assume the scrubber water contains 2 percent phenol by weight.

The mole fraction of phenol in the water is:

Basis:

100 pounds, 98 pounds water and 2 pounds phenol

$$\text{Moles water} = 98/18 = 5.44 \text{ moles}$$

$$\text{Moles phenol} = 2/94 = 0.0213 \text{ moles}$$

$$\text{Mole fraction phenol} = 0.0213/(5.44 + 0.0213) = 0.0039$$

The vapor pressure of the phenol at 100°F (the temperature of the Primary Condenser water) is 0.02 psia. The equilibrium vapor pressure is the mole fraction times the vapor pressure:

$$\text{At } 100^\circ\text{F: } 0.0039 * 0.02 = 0.000078 \text{ psia}$$

The mole fraction of phenol in the vapor is thus:

$$0.000078/14.696 = 5.3E-06$$

The vapor mole fraction is the same as the volume fraction. The weight fraction of phenol in the vapor is calculated as follows:

Basis: 100 moles

$$\begin{aligned}\text{Moles of phenol} &= 5.3E-6 * 100 = 0.00053 \\ \text{Moles of other gas} &= 100 - 0.00053 = 99.99947\end{aligned}$$

Assume the other gas is air with a molecular weight of 29:

$$\begin{aligned}\text{pounds phenol in the 100 moles} &= 5.3E-4 * 94 = 0.0498 \\ \text{pounds air} &= 99.99947 * 29 = 2899.98\end{aligned}$$

Thus, the weight fraction phenol in the vapor is:

$$0.0498/(2899.98 + 0.0498) = 0.0000172 \text{ pounds phenol/pound gas}$$

Thus, if the Primary Condenser water contains 2 percent phenol by weight, the gas in equilibrium with the Primary Condenser water will contain 0.0000172 pounds of phenol per pound of gas.

This calculation is repeated for different concentrations of phenol in the water and the results are shown in Table 2-8.

Table 2-8
Equilibrium Concentration of Phenol in the Gas Phase Above 100°F Water

Weight (% Phenol in Water)	Mole Fraction in Water	Mole Fraction in Vapor	Weight Fraction in Vapor
2	3.89E-03	5.32E-06	1.72E-05
3	5.89E-03	8.01E-06	2.60E-05
4	7.92E-03	1.08E-05	3.49E-05
5	9.98E-03	1.36E-05	4.40E-05
6	1.21E-02	1.64E-05	5.33E-05
7	1.42E-02	1.93E-05	6.27E-05

As shown in the previous section, the gas at 100°F can hold 0.0046 weight fraction of phenol vapor. The gas in equilibrium with water containing 7 percent dissolved phenol holds 0.000063 weight fraction of phenol at equilibrium. The major mechanism for phenol removal will be its solubility in water, not condensation. Even at the 40°F temperature at the HEME, the gas can hold 0.000344 weight fraction of phenol vapor.

Table 2-9 shows the effect of temperature on the equilibrium concentration of phenol in the vapor phase.

Table 2-9 Equilibrium Concentration of Phenol in the Gas Phase Above a Six Percent Water Solution at Various Temperatures				
°F	Phenol (psia)	Mole Fraction in Water	Mole Fraction in Vapor	Phenol Weight Fraction in Vapor
90	0.0136	1.21E-02	1.12E-05	3.63E-05
100	0.0201	1.21E-02	1.64E-05	5.33E-05
110	0.0292	1.21E-02	2.40E-05	7.78E-05
120	0.0419	1.21E-02	3.45E-05	1.12E-04
130	0.0594	1.21E-02	4.88E-05	1.58E-04
140	0.0833	1.21E-02	6.84E-05	2.22E-04

As the temperature increases, the vapor pressure of the phenol increases and the amount of phenol carried over in the vapor increases. Even at 140°F, the concentration of phenol in the vapor is below the equilibrium concentration at the HEME.

We can conclude that no phenol will be removed by condensation at the HEME, phenol will be removed from the gas stream in a water solution. This is even more pronounced for less volatile semivolatiles. In general, water soluble compounds will be removed in the water.

2.3.1.3 Dioxin Emissions

Dioxins are even less volatile than PCBs, so their removal efficiency in the BCDP APCS should be better than PCBs. More importantly, dioxins require oxygen to form. The reduced oxygen levels in the reactor and off-gas system should significantly reduce the potential formation of dioxins.

2.3.1.4 Metals and Particulate Removal

Hazardous waste incinerator regulations have limits on particulate and hazardous metals in the off-gas. The BCDP reactor operates at much lower temperatures than an incinerator, below 900°F, so many of the metals that are volatilized in an incinerator will never leave the soil in the BCDP. Any metals that do come off will be cooled to about 40°F and passed through a HEME, a device designed to remove submicron particles. Metals emissions are expected to be significantly below incinerator standards. Guam's coral soil is naturally low in metals, and metals emissions were not an issue at that site.

Because of the HEME, particulate emissions should also be well below incinerator standards. Although most particulate is removed in the WESP, the HEME provides assurance that no significant quantities of particulates will be found in the off-gas.

2.3.1.5 Volatile Organic Compound Removal

The APCS designed for the BCDP has no provisions other than carbon for removing non-water soluble volatile organic compounds (VOC). The carbon was installed to enhance PCB removal, and would probably become saturated with VOCs. Guam is a clean air area, and VOC emissions were not a regulatory problem. If the BCDP were to be installed in an area that had strict VOC regulations, a small thermal oxidizer could be installed following the Carbon Adsorption unit to remove the VOCs.

2.3.2 Steam as an Inerting Gas

Conventional thermal desorbers draw air over the hot soil to sweep away the contaminants as they are driven out of the soil by heat. Some units have operated using exhaust gas from the burners or even nitrogen as a sweep gas. Steam has the advantage over these other sweep gases because it can be condensed and removed from the gas stream after it has left the kiln. The inerting properties of steam are key to operating the WESP in the APCS.

A WESP is one of the few devices that is capable of removing the submicron organic aerosols exiting the RKR. The WESP contains a bank of tubes that the gas passes through. A wire conductor passes through the center of each tube that is supported by a grid located at the top and bottom of the tubesheet. A maximum of up to 40,000 volts is maintained between the wires and the tubes. Particles, including organic aerosols, moving through the tube acquire an electrical charge from the

wire. They are then electrostatically attracted to the tube wall, which has an opposite charge. The particulates contact the tube walls and agglomerate.

Water is continuously sprayed into the bottom of the tubes concurrent with the gas flow. This water flushes the walls of the tubes and washes the agglomerated particulates off the tubes.

Because of the high voltage that must be maintained between the wire and the tube, the WESP sparks, typically several times a minute. A high energy spark is an excellent ignition source. The gas leaving the kiln contains organics from the soil, an excellent fuel. The Lower Explosive Limit (LEL) of organics varies, but typically it is between 1 and 5 volume percent of the gas in air. LEL is defined as the lowest concentration of organics in a homogenous mixture of air and organic(s) that is sufficient to allow an explosion or fire to occur when an ignition source is present.

The high energy spark is unavoidable if a WESP is to be operated. The quantity and composition of organics coming off the soil are uncontrollable. Of the three elements of the fire triangle, oxygen, fuel, and ignition source, oxygen was the only controllable variable.

2.3.2.1 Minimum Oxygen Concentration

Just as there is a LEL for organics in air, there is also a Minimum Oxygen Concentration (MOC) necessary for combustion. Like the LEL, this concentration depends on the specific organic(s) involved. The MOC also depends on the gas used to dilute the oxygen. The U.S. Bureau of Mines has conducted extensive testing of MOC [12] and their data provided important guidance in determining the MOC for the operation of the WESP.

Most published MOC data is for inerting with carbon dioxide and nitrogen. The National Fire Protection Association (NFPA) 69, Standard for Explosion Prevention Systems [4], provides tabulated values for the maximum safe oxygen concentration for nitrogen inerting and carbon dioxide inerting of various organics. NFPA 69 also provides general guidelines for inerting systems including procedures for performing temperature corrections on the published data. The Society of Fire Protection Engineers (SFPE) Handbook of Fire Protection Engineering, 1988, provides guidance on calculating the LELs of mixtures of organics.

In general, inerting hydrocarbons with carbon dioxide gives an MOC between 12 and 15 percent oxygen, while nitrogen inerting yields an MOC of 10 to 13 percent oxygen. The most flammable

gas presented in the literature is hydrogen, which has a MOC of 6 percent with carbon dioxide inerting and 5 percent with nitrogen inerting. Table 2-10 provides data on the maximum oxygen percentage to prevent ignition for some common flammable gases. While steam inerting data were scarce, the available data indicate that steam is a better inerting agent than nitrogen, but not quite as good as carbon dioxide. In general, carbon dioxide inerting allows about 20 percent more oxygen than nitrogen, and steam inerting allows about 10 percent more oxygen.

Table 2-10
Maximum Permissible Oxygen Percentage to Prevent Ignition of Flammable Gases and Vapors
Using Nitrogen and Carbon Dioxide for Inerting

	N ₂ -Air		CO ₂ -Air	
	O ₂ % Above Which Ignition Can Take Place	Maximum Recommended O ₂ %	O ₂ % Above Which Ignition Can Take Place	Maximum Recommended O ₂ %
Acetone	13.5	11	15.5	12.5
Benzene (Benzol)	11	9	14	11
Butadiene	10	8	13	10.5
Butane	12	9.5	14.5	11.5
Butene-1	11.5	9	14	11
Carbon Disulfide	5	4	8	6.5
Carbon Monoxide	5.5	4.5	6	5
Cyclopropane	11.5	9	14	11
Dimethyl butane	12	9.5	14.5	11.5
Ethane	11	9	13.5	11.0
Ether	--	--	13	10.5
Ether (Diethyl)	10.5	8.5	13	10.5
Ethyl Alcohol	10.5	8.5	13	10.5
Ethylene	10	8	11.5	9
Gasoline	11.5	9	14	11
Gasoline				
73-100 Octane	12	9.5	15	12
100-130 Octane	12	9.5	15	12
115-145 Octane	12	9.5	14.5	11.5
Hexane	12	9.5	14.5	11.5
Hydrogen	5	4	6	5
Hydrogen Sulfide	7.5	6	11.5	9
Isobutane	12	9.5	15	12
Isopentane	12	9.5	14.5	11.5

Table 2-10 Maximum Permissible Oxygen Percentage to Prevent Ignition of Flammable Gases and Vapors Using Nitrogen and Carbon Dioxide for Inerting				
	N ₂ -Air		CO ₂ -Air	
	O ₂ % Above Which Ignition Can Take Place	Maximum Recommended O ₂ %	O ₂ % Above Which Ignition Can Take Place	Maximum Recommended O ₂ %
JP-1 Fuel	10.5	8.5	14	11
JP-3 Fuel	12	9.5	14	11
JP-4 Fuel	11.5	9	14	11
Kerosene	11	9	14	11
Methane	12	9.5	14.5	11.5
Methyl Alcohol	10	8	13.5	11
Natural Gas (Pittsburgh)	12	9.5	14	11
Neopentane	12.5	10	15	12
n-Heptane	11.5	9	14	11
Pentane	11.5	9	14.5	11.5
Propane	11.5	9	14	11
Propylene	11.5	9	14	11

The data in Table 2-10 are from reference [12].

No information or calculation protocols were found for adjusting MOC for temperature. Most LEL values are reported at ambient temperature, 77°F. NFPA 86, Appendix E, Pages 86-71 provides an LEL correction factor for different temperatures. Higher temperatures decrease the organic concentration necessary for flammability. In general, there is a 5 percent reduction in the LEL value for each 100°F rise in temperature above 77°F. Moving from 77°F to 212°F reduces the required organic concentration by a factor of 0.94.

Ultimately, the decision of what MOC to use in the WESP was based on the above reference data and engineering judgement in areas where the protocols fell short of providing sufficient data. The WESP would be operated at an oxygen content below 5 percent. If the oxygen content ever reached 5 percent during operation, the power to the WESP would automatically switch off. This instantly removes the ignition source.

2.3.2.2 Measurement of Oxygen in the WESP

For the proposed control system to work, the oxygen content of the gas in the WESP has to be measured on a real time basis. The gas entering the WESP is dirty with particulate, organic vapors, and organic aerosols, and is high in water vapor. No instrument could be found that would continuously monitor this gas and report the oxygen content on a real time basis. While the gas leaving the WESP is clean, it is still water saturated, and a reliable, real time instrument to measure oxygen could not be located.

The solution is to insure that the gas in the WESP is water saturated and use the temperature to measure the oxygen content of the gas. If air is water saturated, the water vapor content (humidity) of the air is dependent on the temperature. By measuring the temperature of the gas, the air-water vapor ratio can be determined.

The assumption is that the gas in the WESP consists of water vapor and air, and that the air is 21.9 volume percent oxygen. This assumption is conservative. To the extent that organic vapors are in the WESP gas, the oxygen content will actually be lowered. Organics, like steam, will displace air.

Figure 2-2 shows the oxygen content of air saturated with water vapor as a function of temperature. The graph was constructed by determining the saturated air/water vapor ratio at different temperatures from a psychometric chart and then calculating the oxygen content of the air. The oxygen content reaches 5 percent at a temperature of 198°F.

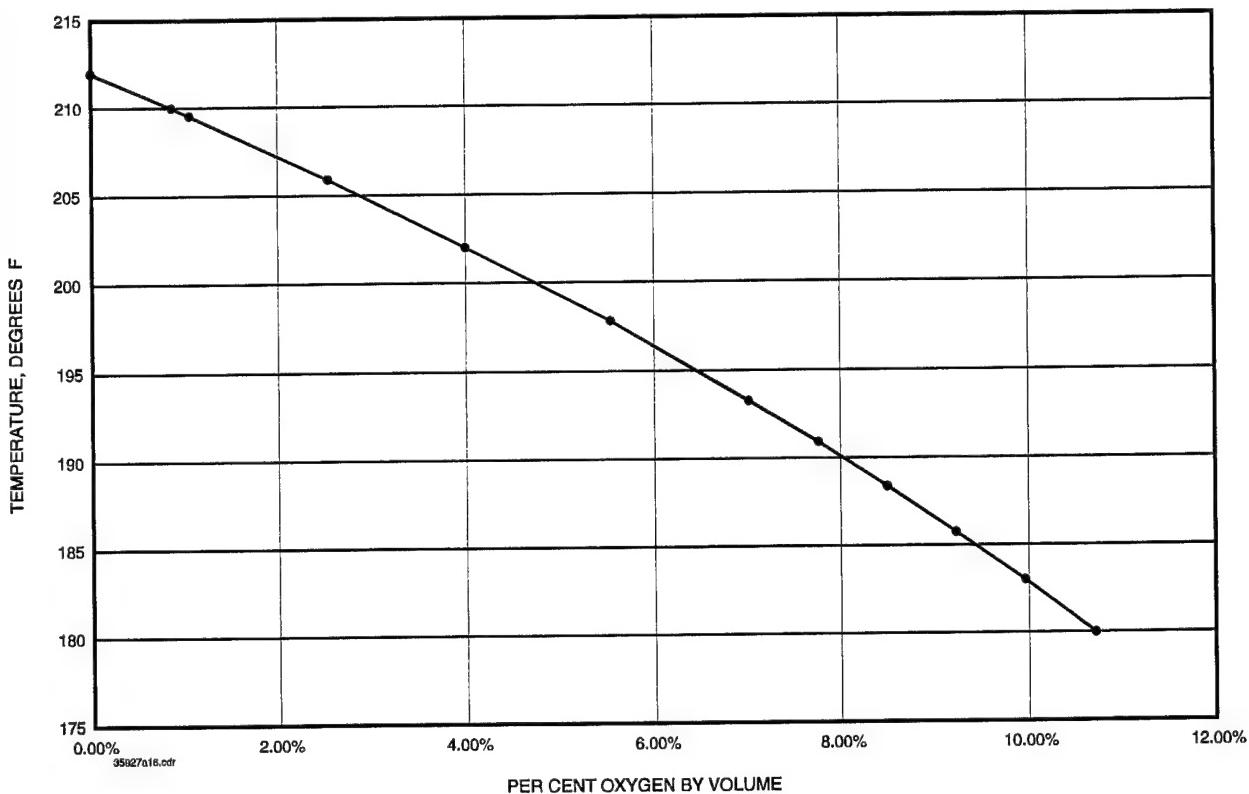


Figure 2-2
Percent Oxygen Versus Temperature in Water Saturated Air

As an example calculation, the psychometric chart shows that at 198°F air contains 1.917 pounds of water vapor per pound of dry air. Thus, 100 pounds of dry air would contain 191.7 pounds of water vapor. The volume percent air in this mixture is calculated by determining the mole percent, which is the same as the volume percent:

$$100 \text{ pounds air} = 100/29 = 3.45 \text{ moles of air}$$

$$191.7 \text{ pounds water} = 191.7/18 = 10.65 \text{ moles of water}$$

$$\text{Total moles} = 3.45 + 10.65 = 14.10$$

$$\text{Mole (and volume) fraction air} = 3.45/14.10 = 0.24$$

Air is 21.9 volume percent oxygen. The oxygen content in the saturated gas at 198°F is:

$$0.219 * 0.24 = 5.4 \text{ percent}$$

2.3.2.3 WESP Oxygen Control System

To use the control method, the gas in the WESP must be water saturated. This is assured by several steps. First, steam is used as a sweep gas in the kiln and the kiln is operated with attention to excluding leaks. Moisture from the soil goes into the kiln off-gas and further increases the water content of the off-gas. The quench, where water is sprayed into the off-gas, is located just before the WESP, and the gas enters the quench at a temperature well over 212°F. Quench water is evaporated and added to the off-gas stream.

After the gas passes through the quench it enters the WESP and passes over the spray nozzles as it enters the WESP tubes. This contact with water sprays insures that the gas is water saturated. If the water sprays stopped, the gas might not be saturated. The water going to the quench and WESP spray tubes passes through a magnetic flow meter. The normal flow is between 40 and 50 gallons per minute (gpm). If the flow drops to 35 gpm, an alarm sounds. At 30 gpm, electrical power to the WESP is automatically shut down. If the water necessary to insure that the gas is saturated stops, the ignition source is removed to prevent a possible explosion.

Gas temperature is measured as the gas leaves the WESP. Since there is no heat source in the WESP tubes, the gas leaving the WESP is not hotter than the gas in the tubes where the sparking occurs. This thermocouple triggers an alarm at 203°F (an oxygen content of 4 percent) and automatically shuts down power to the WESP at 198°F (5 percent oxygen).

As a final safety, low pressure (15 pounds per square inch gage [psig]) steam is injected into the quench. This steam flow is controlled by the WESP gas outlet temperature. The outlet temperature is a set point, and the quench steam is metered through a control valve to maintain the set point. If additional air infiltration occurs, or additional heat loss occurs in the system, the quench steam flow will automatically increase to maintain the desired oxygen content.

2.4 Air Pollution Control System Equipment

This section discusses the equipment in the APCS.

2.4.1 Multicloner

The cyclone from the demonstration run was replaced with a Multicloner that contained three small cyclones. During the demonstration runs, organics would condense in the cyclone and wet the fines. This caused plugging problems in the cyclone discharge. To minimize condensation in the full-scale system, the cyclone was insulated and the bottom conical section of the cyclone where the air is stagnant was heat traced. Material dropping out of the cyclone went through a rotary star valve and from there fell through a flexible bellows tube into a 55-gallon drum for collection. The flexible bellows tube allowed the drum lid to be easily removed to change drums.

Some plugging problems were experienced at the rotary valve, but the material in general stayed much drier than it did during the demonstration runs because of the insulation and heat tracing.

2.4.2 Wet Electrostatic Precipitator

The WESP quench system was custom designed for the BCDP. The gas exiting the cyclone drops into the quench section at the entrance of the WESP, shown in Figure 2-3. Process water is continuously sprayed into the gas in the quench section to cool the gas down below 212°F and fully water saturate the gas.

The most important consideration in the operation of the WESP is to ensure that an explosive mixture never forms inside the unit. Organics from the soil provide fuel and the frequent sparking that occurs in the WESP provides an excellent ignition source. As explained in Section 3.0 of this report, water vapor (steam) is used to displace oxygen in the WESP and ensure that there is never enough oxygen to support a flame or explosion. The two elements that combine to provide this assurance are a water saturated gas and a sufficiently high gas temperature to ensure that water vapor is displacing the oxygen. The continuous water spray at the quench, as well as a continuous water spray into the bottom of the WESP tubes, provides assurance that the gas is saturated. The thermocouple measuring the temperature of the gas exiting the WESP (TE524 on the Piping and Instrumentation Diagrams [P&ID]) provides assurance that the temperature is high enough. The temperature indicator at the WESP gas outlet, TE524, was set to alarm at 203°F and shut the electrical power to the WESP down at 198°F.

In addition to water, 15 psig steam from the boiler is injected into this quench section. The quench steam flows through a control valve, FY714, which is controlled by the temperature of the gas leaving the WESP. The operator sets the desired temperature of the exit gas and the steam flow

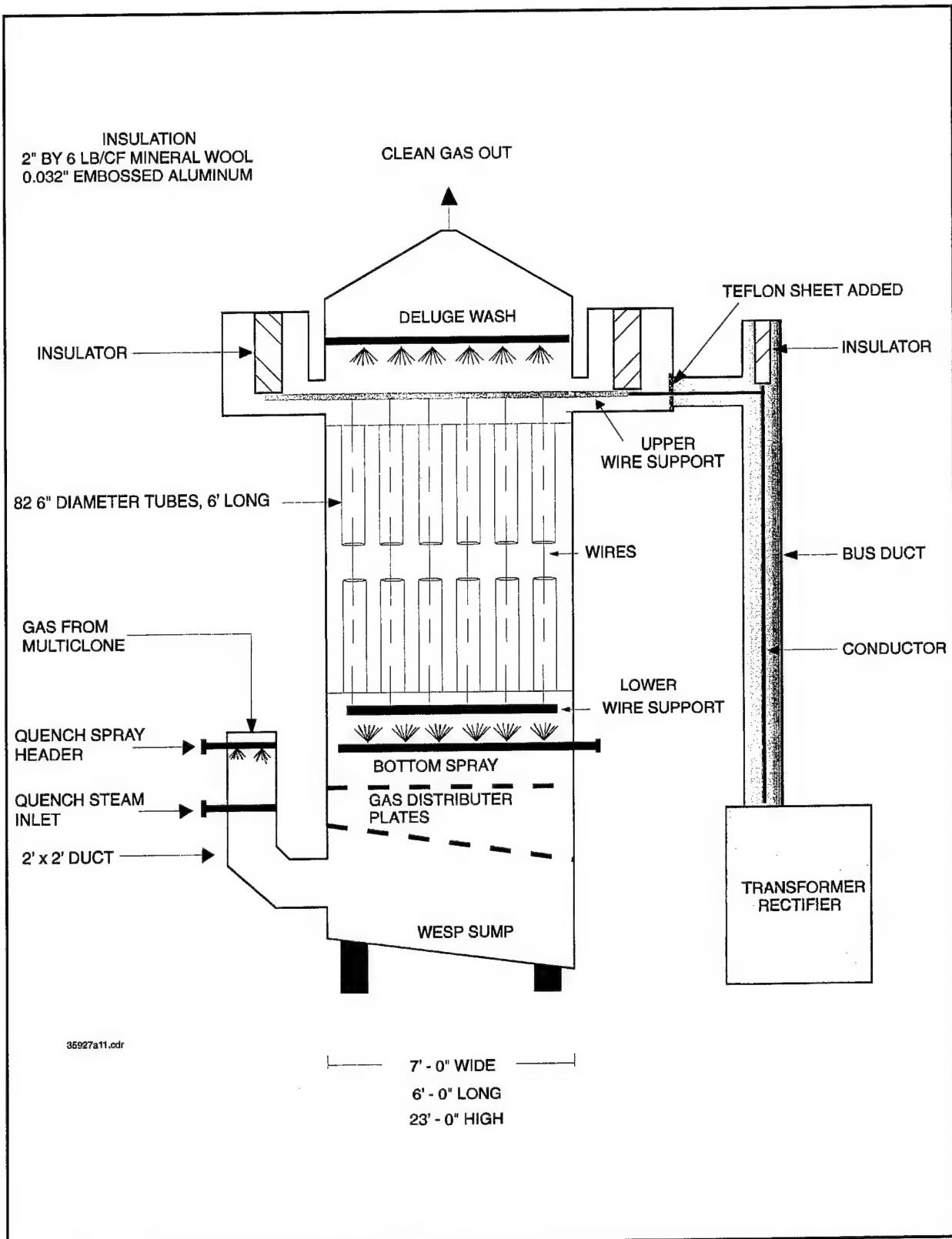


Figure 2-3
Wet Electrostatic Precipitator (WESP)

control valve is automatically adjusted by TE524 to maintain that temperature. Recall that the entire off-gas system from the kiln to the ID Fan is operated under a vacuum. If a leak should occur that allows air into the system somewhere before the WESP, the air will quickly heat up and evaporate water. The evaporation will cool the gas and the temperature as measured by TE524 will drop. The lower temperature will automatically open the steam valve to bring the temperature back up. As the temperature increases, additional water evaporates to dilute the oxygen in the infiltrated air down to the target operating level of less than 4 percent oxygen.

It was not known during the design whether this steam injection would be used on a regular basis because the amount of air infiltration and heat loss in the system could only be estimated.

The gas passes through the quench section into the bottom plenum of the WESP. Perforated plates below the WESP tubes are used to distribute the air flow uniformly across the tubes. Spray nozzles are located along the entrance of the tubes and water is constantly sprayed up into the tubes and mixed with the gas. In addition to ensuring that the gas is water saturated, this water also washes the tube walls. The water drips down off the tubes and accumulates in the WESP sump. The WESP recirculation pump takes water from the sump and pumps it back around to the quench and WESP tube spray nozzles. A level control meter (LIC524) ensured that there was always enough water in the sump to provide suction to the WESP recirculation pump. At a low sump level, LIC524 opens a solenoid valve (LV5248) which added process water to the sump.

The WESP recirculation pump discharges through a magnetic flowmeter (FT521). A continuous flow of water was necessary to ensure saturation, a key safety feature. FT521 normally recorded a flow between 40 and 50 gpm. It was tied to an alarm that sounded if the flow should drop to 35 gpm and it would automatically turn off the power to the WESP if the flow dropped to 30 gpm. This removes the ignition source instantly.

The recirculation pump initially used on the WESP was a chemical sealed diaphragm pump. The pump had to be able to operate at a low net positive suction head (NPSH) (5 to 8 feet of water), pump a slurry, and also ensure that no air was added to the WESP. The chemical sealed diaphragm pump had two diaphragms on each side with a colored liquid between the diaphragms. If one of the diaphragms should rupture, this liquid would escape and the operator would be able to tell either from a loss of liquid or a change in color in the liquid that a diaphragm had failed. A number of operating problems were encountered with this pump and it was later replaced with a progressing

cavity pump. The progressing cavity pump meets all the requirements previously outlined for this pump and has no compressed air associated with it, thus, it is inherently much safer. Unlike a diaphragm pump, a progressing cavity pump cannot be run dry, and an interlock was added to stop the pump if the flow stopped.

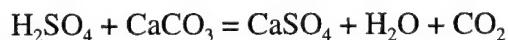
A blowdown line branched off the WESP recirculation line that carried waste liquid to the wastewater treatment plant (WWTP). The blowdown flow was preset and controlled by the flow control valve (FV528). A Fin Fan air cooled heat exchanger left from the demonstration runs was used to cool the blowdown flow to prevent it from raising the temperature in the WWTP.

An acid addition system was added to the WESP recirculation line to reduce solids buildup. The water accumulating in the WESP sump had a pH of about eight. Some of this is due to the sodium bicarbonate and sodium carbonate coming from the reactor, but it is also due to the high levels of calcium carbonate in the naturally occurring soils of Guam, a coral island. Titration studies in the laboratory showed that 60 to over 80 percent of the solids could be dissolved if the pH were reduced to six. Coral reacts with sulfuric acid to produce water, carbon dioxide gas, and calcium sulfate salt. This was an effective means of reducing the overall solids buildup in the WESP. The pH was not taken below six to insure that no acid corrosion damage occurred.

Ninety-three percent sulfuric acid was available on Guam. This acid was added directly to the WESP recirculation line after the pump and magnetic flow meter. Initially, the acid was added before the flow meter, but the meter reading fell to zero as soon as the acid was added. This was probably because of gas bubbles that form in the liquid where the acid is added. The injection point was moved upstream of the meter.

Dilute (around 5 to 50 percent) sulfuric acid is very corrosive, and the 200°F temperature of the WESP recirculation water makes it even more corrosive. Teflon tubing was used to pipe the acid to a teflon injection valve. The steel pipe was replaced with chlorinated polyvinyl chloride (CPVC) pipe at the injection tee and for about three feet downstream of the injection point. This gave the acid time to mix and react before reaching the steel pipe.

The acid reacts with the coral to form the acid salt, carbon dioxide, and water:



The carbon dioxide joins the gas stream and the calcium sulfate dissolves in the water. The calcium sulfate is only soluble at about 0.2 percent in water, but the solids in the WESP blowdown were typically about 0.25 percent. Calcium chloride is much more soluble and hydrochloric acid was considered instead of sulfuric. The hydrochloric acid was only available in drums as a 20 percent solution and was much more expensive per pound of acid. Using hydrochloric acid would not have been economical.

The quantity of gas released into the gas stream was insignificant. Acid addition started August 5, 1996, after the stack test. The reduction in residuals started on that date.

Acid addition was economical in its own right. Any solids captured in the WESP would ultimately become filter cake from the water treatment plant. In fact, a pound of dry solids entering the WESP would become two pounds of wet filter cake, a contaminated residual, that would have to be shipped off island for disposal on the mainland. After deducting the cost of the acid, each ton of fines dissolved actually saved the project \$1,000. This figure is based on the cost of shipping material from Guam to the mainland for disposal by incineration.

Before the WESP started up, an oil-water separator to remove both sinking and floating organics was built and added to the WESP sump. It covered about 20 percent of the sump footprint below the WESP tubes. A lid on the separator collected the water and directed it into the feed end of the separator. Two pipes from the separator penetrated the WESP wall and were for batch draining heavy and light organics that accumulated in the WESP. This unit never recovered any oil, and after a few weeks of operation, plugged with solids. The separator was left in the WESP for the duration of the job.

The WESP removes particulate, including condensed organics, with electrostatic force. Each of the tubes through which the gas passes as it goes through the WESP has a wire hanging down through the center of the tube. The wire and the tube are oppositely charged. The particle takes on the charge of the wire and then is attracted to the tube wall. As shown in Figure 2-3, these wires are supported by a metal grid at each end of the tube bank. Since this metal grid has a charge that is opposite from that of the body of the WESP, it must be supported off of the WESP frame by insulators.

In a typical WESP design, these insulators are set at the top of the WESP and outside air is used to flush the insulators and keep moisture from condensing on them. If moisture or anything else condenses on these insulators, it can provide a pathway for current to flow. If current flows across the insulator, it will create a short that will reduce the operating voltage (and the gas cleaning efficiency), or take the WESP out of service. Introducing outside air into the WESP was unacceptable because that would introduce oxygen into the WESP. To get around this problem, the insulators were mounted in compartments built on the side of the WESP. This removed them from the air stream flowing through the WESP.

The Transformer Rectifier (TR) that provided the high voltage direct current to the WESP rests on the ground. Power is conveyed from the TR to the WESP through a bus duct that connects the TR on the ground to the insulator compartment. After the unit arrived on Guam, electrical heating tape and insulation was added to this bus duct. Keeping the bus duct hot helped prevent moisture from condensing in this area.

A teflon sheet was added to cover the opening where the bus duct entered the body of the WESP. The bus bar traveled through a three-inch hole in the teflon. This was another modification to keep contaminants out of the bus duct.

A set of spray nozzles was also located at the top of the WESP tubes. These nozzles could be used to provide a deluge flush for cleaning the tubes on an as-needed basis.

2.4.3 Primary Condenser

Gas leaving the WESP entered the Primary Condenser, a vertical shell and tube heat exchanger setting above a knockout pot. The gas passed through the tube side of the exchanger and cooling tower water circulated on the shell side. Steam condensed in the tubes and drained into the knockout pot. The cooled noncondensable gases flowed out of the tubes, made a 180-degree turn, and left through the gas exit pipe. A level indicator controller on the knockout pot energized the pumps at high level to pump condensate out to the WWTP.

The heat exchanger contained one-inch tubes. If the gas stream entering the tubes contained significant amounts of oil and particulates, there is a danger of fouling the tubes. The design depended on two factors to keep this from happening. If the WESP is operating properly, the gas leaving the WESP should be clean. Second, a large amount of the gas is steam which condensed on

the walls of the tubes and ran down the tubes into the knockout pot at the bottom of the exchanger. This water continuously flushed and cleaned the tubes.

A gas bypass was added around the WESP and Primary Condenser that would direct off-gas from the cyclone directly to the Venturi Scrubber (the rapid start configuration). If the WESP had to be taken out of service for a long period of time, the unit could be bypassed. The main reason for this bypass was to protect the Primary Condenser. While the WESP could be opened up and cleaned easily, cleaning the one inch tubes in the Primary Condenser was more difficult.

2.4.4 Venturi Scrubber/Bubble Tray Scrubber

Gas leaving the Primary Condenser flowed first through the Venturi Scrubber and then made a 180-degree turn and went through a Bubble Tray Scrubber. These scrubbers were used for particulate removal during the Rapid Start when the WESP and Primary Condenser were not yet available. In the full-scale configuration, the scrubbers were not used and, in fact, the gas flow through them was too low to make use of this equipment.

The Bubble Tray Scrubber had two steel access plates that were replaced by plexiglass. A strong flashlight shining through the plexiglass into the unit made it possible to qualitatively measure the amount of mist and fines in the gas. When the WESP was operating well, the gas inside the Bubble Tray Scrubber was clear, and the flashlight beam could not be seen. If the WESP was operating at low efficiency, the light beam could be seen because of the particulate in the scrubber (the Tyndall effect). If the WESP was turned off, a dense fog could be seen through this plexiglass, and the back of the scrubber could not be seen.

2.4.5 Chiller Condenser

The Chiller Condenser is a heat exchanger with gas passing through the shell side and ethylene glycol/water solution at about 25°F passing through the tube side. This unit cooled the gas further, condensed some additional water, and allowed some additional condensation of organics. The refrigeration system that supplied the chilled glycol/water solution was a packaged unit in a separate building. The refrigeration system used cooling tower water as the heat rejection medium. From the Venturi Scrubber through the rest of the APSCS, CPVC piping was used. CPVC is much lighter and easier to use than steel, and also has better insulation properties.

The gas exiting the Chiller Condenser was colder than the ambient temperature on Guam. As a result, the gas heated up as it traveled through the rest of the system and that heat up ensured that the gas was dry. This meant that no water would condense in the carbon system that came after the Chiller Condenser. Any mist of water droplets that left the Chiller Condenser were removed by the HEME.

2.4.6 High Efficiency Mist Eliminator

Gas from the Chiller Condenser passed through one of two HEMEs piped in parallel. The mist eliminator vessel is a steel tank with a flange ring about one foot from the top of the vessel, shown in Figure 2-4. The cage holding the HEME element bolts down on this flange and utilizes a thick teflon gasket to prevent gas leaks. Gas passed from the outside to the inside of the cylinder where it exited through the top of the HEME tank.

The HEME was designed to allow the elements to be replaced in the field as needed. The element consisted of two sleeves, each about 1.5 inches thick. The inner sleeve was first placed on the cage, then a slightly larger second sleeve was pulled over the first sleeve. A prefilter bag was then placed over the element for solid particulate removal. This bag costs \$300 versus \$2,400 for the elements, and was relatively easy to replace.

To allow for removal and replacement of the HEME elements, a removable section was cut in the roof of the building and an I-beam was mounted about 8 feet above the roof. An electric wench was mounted on the I-beam that could be used to extract the element, move it to one side, and lower it to the building floor.

Like the WESP, this unit is nearly 100 percent efficient in removing particles above three microns in size and 99 percent efficient in removing smaller particles. Also, like the WESP, the HEME has almost infinite turndown. The lower the gas velocity through the element, the more efficiently the HEME operates. Organics that are taken out in the HEME will wet the fabric, and after a sufficient buildup of organics or other liquids, the liquid will drain to the bottom of the element. Since the gas flowed from the outside to the inside of the cylinder, the liquid tended to flow towards the inside wall of the element and accumulate in the bottom of the HEME cage.

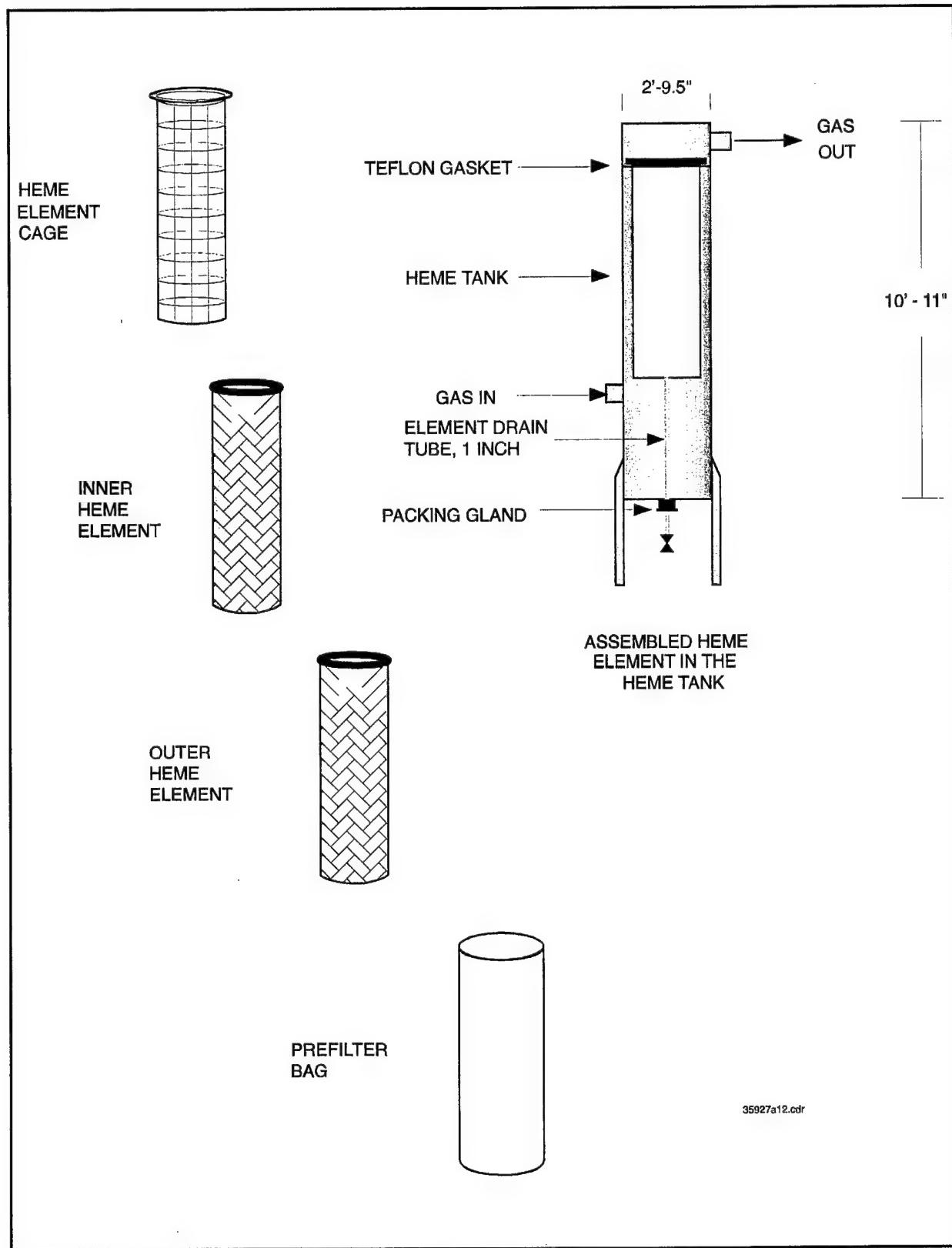


Figure 2-4
High Efficiency Mist Eliminator (HEME)

A drain pipe from the bottom of the HEME cage to the outside of the element allowed any accumulated liquids to be removed. To drain a HEME, the flow was switched to the standby HEME, the isolated HEME was drained, then put back on line.

Initially, the element drain tube dropped to within 2 inches of the bottom of the HEME tank. At least 30 inches of water was added to the bottom of the HEME tank to submerge the drain tube and provide a seal. Collected liquid would mix with the water and periodically be drained.

This was later modified and the 1-inch element drain tube was extended down through a 2-inch valve at the bottom of the tank. A packing gland was constructed to seal the 1-inch pipe where it passed through the 2-inch valve. A valve was placed on the end of the 1-inch pipe that could be opened periodically to drain the HEME element. This modification allowed any material that collected in the HEME to be drained directly instead of diluting it in seal water.

A steam injection point was added to the HEME tanks. The HEME elements were fiberglass and could tolerate temperatures over 200°F. To clean a plugged HEME, the unit was isolated and steam was blown into the tank. Condensate was drained out of the element drain.

The HEME is the most likely place where co-solubility removal of organics will be encountered in this system. Technically, the HEME only removes condensed material; however, if organic liquids build up in the element, organic vapors that are soluble in the organics in the HEME can be removed by solubilization into that liquid. This effect would be difficult to calculate without knowing the actual organic compounds involved.

2.4.7 Induced Draft Fan

Gas leaving the HEME travels through the ID Fan. The BCDP utilized a rotary positive blower with a variable speed drive motor.

The ID Fan speed was controlled by the vacuum in the RKR. The operator could enter a set point vacuum and the Fan speed would vary to maintain that set point in the kiln. Maintaining a negative pressure in the kiln and through the bulk of the air capture system ensured that contaminated gas did not escape the system. If there were any leaks, air would be leaking in instead of contaminated gas leaking out.

This type of blower can only be used on a very clean gas stream. The rotating lobes are not lubricated and very close clearances between the lobes as they spin provide the seal. Any solids getting into these areas of tight clearances could damage the blower.

2.4.8 Air Treatment Carbon

From the ID Fan the gas passed through two air Carbon Adsorption vessels in series. Each vessel contained 600 pounds of vapor phase carbon. Organic vapors in the gas as well as residual PCBs were removed by the carbon. PCBs have a higher affinity for carbon than the lower molecular weight volatile compounds, and would displace those more volatile compounds once the carbon became saturated.

From the carbon, the gas traveled to the vent stack and exited to the atmosphere.

2.5 Wastewater Treatment Plant

The WWTP is a conventional plant utilizing flocculation and clarification followed by oleophilic media to remove oil and finally Carbon Adsorption treatment. Much of the WWTP was assembled using equipment left by the Demonstration Contractor.

2.5.1 Surge Tank

All the flows entered the WWTP at the Surge Tank. The major process flows entering the system were WESP recirculation water and condensate from the Primary Condenser. Intermittent flows included washdown water, decontamination pad water, laboratory sump waste, and storm water. These flows were mixed by air sparging the Surge Tank to provide (to the extent possible) a uniform feed to the rest of the WWTP. The Surge Tank was a bladder tank containing two bladders to maintain secondary containment. Water was pumped from the Surge Tank into Tank S-6020 which was initially installed as an oil-water separator for separating heavy oils; however, no such oils ever accumulated.

2.5.2 Flocculation System

Polymer was injected into the wastewater in a rapid mix zone as it flowed out of Tank S-6020. A small agitator mounted on the side of the tank provided rapid mixing. The wastewater and polymer gravity flowed into the polymer mixing tank, T-6030. A variable speed flocculation mixer was mounted on this tank to flock the solids in the wastewater. Four vertical baffles were mounted on the side of the flocculation tank to aid in mixing.

2.5.3 Clarifier

The clarifier was a fiberglass reinforced plastic tank that had been purchased on the island and then modified to serve as a clarifier. Wastewater entered the clarifier via a stilling well in the top center of the unit and solids settled to the bottom. The overflow weir consisted of a square of 4-inch polyvinyl chloride pipe perforated with one-inch holes and connected to the clarifier discharge pipe. The water level was controlled in the clarifier about 3 inches above this overflow pipe to collect any floating oil. No significant amount of floating oil was observed during the rapid start, but this provision to separate such oil was made in case some appeared either because of a change in operating conditions, or because of a change in the type of soil being treated.

Water flowed from the clarifier to the clarified water tank, T-6065. A level control valve on the pump discharge line from the clarified water tank maintained a constant level in the tank. Since the clarifier overflow line entered the clarified water tank below its normal operating level, the level in the clarifier was always the same as the level in the clarified water tank.

2.5.4 Bag Filters and Oleophilic Media Drums

Water from the clarified water tank was pumped through one of two bag filters operating in parallel. The bag filters were 70 micron. From the bag filters the water flowed through two Oleophilic Media drums in series. These were 55-gallon drums containing a mixture of clay and anthracite. This material adsorbed oils in the wastewater, including emulsified oils.

2.5.5 Water Carbon

Water flowed from Oleophilic Media into two tanks containing carbon that were piped in series. From the Water Treatment Carbon Tanks the treated wastewater flowed into the Treated Water Tank, T-6080. This tank supplied treated water to the rest of the plant. Most of the treated water was pumped to the ash belt and used to cool the reactor product. A level indicator on the Treated Water Tank opened a potable water line to add make-up water to the tank at low level.

A bypass was installed around the Bag Filters and Water Treatment Carbon so that clarified water could be returned back to the plant as process water, largely for the WESP.

Sludge from the clarifier was pumped to a plate and frame filter press for dewatering. The filter cake was dropped into a bin below the filter press and shoveled from the bins into drums for final disposal.

2.6 Controls and Instrumentation

The BCDP computer control system was developed from an off-the-shelf software. The software allows the user to build graphical screens representing the process and to utilize the computer to control the process. Alarm points can be inserted and edited at any time, and switches can be installed on the computer screen to start and stop equipment.

Figure 2-5 shows the screen that depicted the operation of the RKR. This and subsequent screens showed real time data on the computer monitor. The kiln screen shows the four burner temperatures that record conditions outside the rotating steel shell. The six bed temperatures and the ash temperature show the thermal conditions within the kiln. Kiln vacuum, rotation, and feed rate are also shown along with the pounds per hour of steam sweep gas flow. The lower left-hand corner shows the diesel fuel supply in gallons. The two pairs of knife gate valves on the soil feed and product discharge end of the RKR are black when closed and green when open. The actual level in the diesel fuel tank is also depicted graphically.

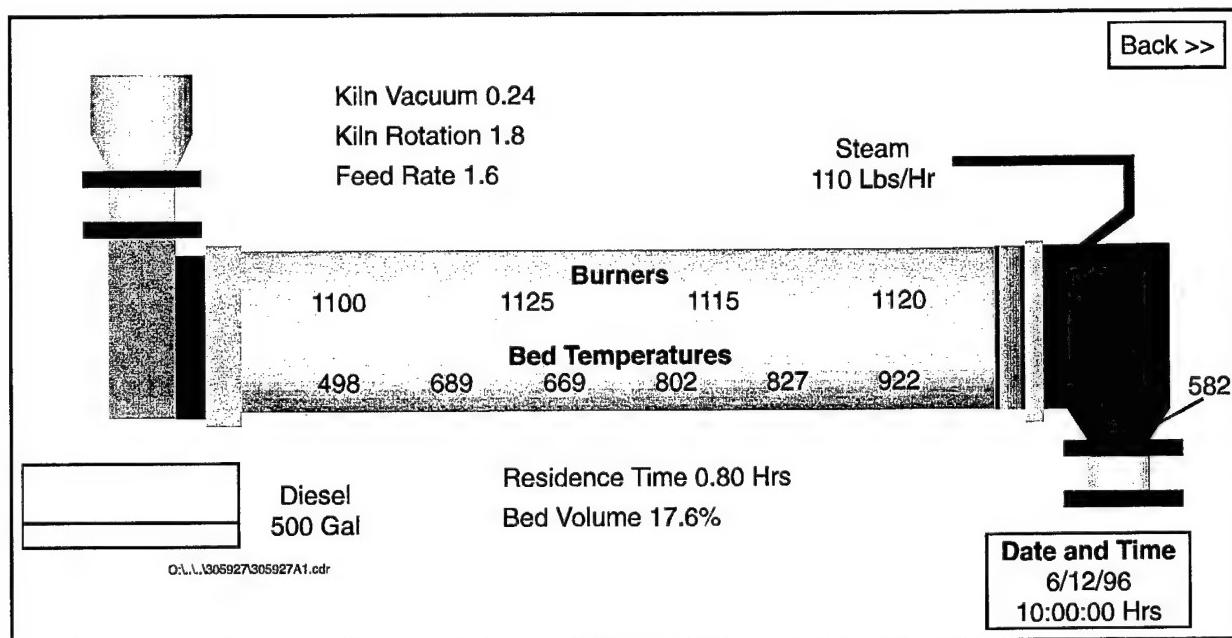


Figure 2-5
RKR Control Screen

The kiln screen also shows residence time and bed volume. These parameters are calculated from the system's operating conditions and shown on a real time basis. The residence time equation is from [7], Pages 20-33.

$$T = 0.23L / (SN^{0.9} D)$$

where T = Time of passage, minutes
 L = Kiln length, feet = 30
 S = Slope, feet per foot = 0.0289
 N = Speed, rpm
 D = Kiln diameter, feet = 2.917

If the kiln is rotating at 1.7 rpm, the time of passage (residence time of material in the kiln) is:

$$T = 0.23 * 30 / (0.0289 * 1.7^{0.9} * 2.917) = 50.8 \text{ minutes}$$

Note that the residence time of the material in the kiln is independent of the soil feed rate. The bed volume is calculated from the kiln throughput in tph. The density of the material in the kiln is 91 pounds per cubic foot and the total kiln volume is 249 cubic feet. As a general rule, the bed volume should not exceed 15 percent. For the example given above, if the kiln feed rate is 1.5 tph, the bed volume is the volume of the soil in the kiln divided by the total kiln volume, or:

$$\text{Bed Volume} = (1.5 \text{ tons/hour} * 50.8 \text{ hours/60} * 2,000 \text{ pounds/ton}) / (91 \text{ pounds/ft}^3 * 249 \text{ ft}^3) = 11.2\%$$

The air pollution control screen is shown in Figure 2-6. This screen shows temperatures and pressure drops throughout the APCS. The WESP, Primary Condenser, and Venturi Scrubber accumulate water in their sumps and are on a level control system. The actual liquid levels are graphically depicted on the screen. All three of these units have a high level alarm, and the computer sounds an audible alarm, as well as indicating the alarm on the screen. Two key variables, kiln vacuum and feed rate, are shown on this screen.

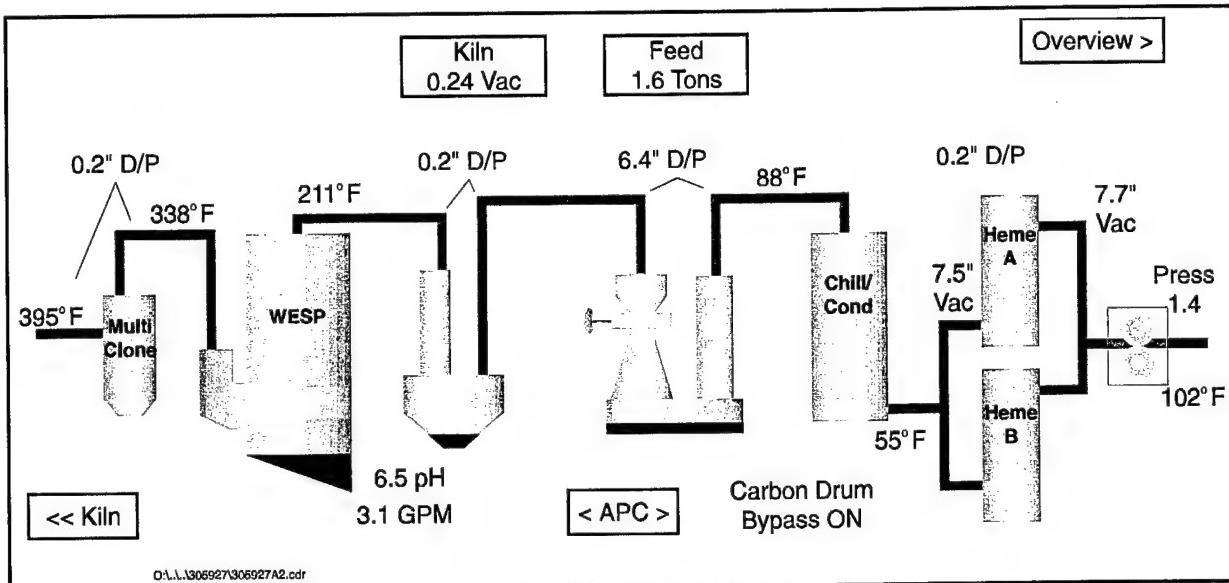


Figure 2-6
APCS Control Screen

Figure 2-7 shows the detailed ID Fan screen. This screen shows the rpm, as well as inlet and outlet pressure and the pressure drop across the Fan. The screen also shows the temperature in and out of the air treatment carbon.

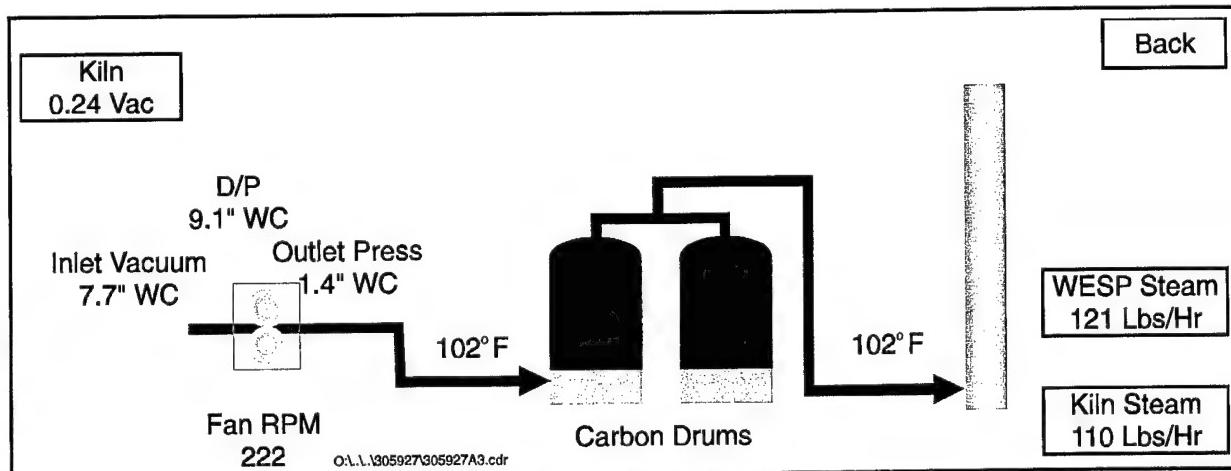


Figure 2-7
ID Fan Control Screen

Figure 2-8 shows the WESP detail screen containing temperatures and flows around the WESP. The process water make-up valve is a solenoid on-off valve. The valve changes color from black to

green when it opens. The recirculation water flow in gpm is also shown along with the pH adjustment system. The percent output of the acid addition pump is displayed along with the pH of the treated WESP recycle. If the WESP shut down, it changed color from gray to red and a reset button appeared on the screen to the right of the WESP. When the conditions causing the shutdown were neutralized, the operator restarted the WESP from the computer.

An alarm summary shows at the bottom of the screens. When a set point exceedance triggered an alarm, the computer caused an audible alarm to sound and the condition causing the alarm was shown in the alarm summary table at the bottom of the screen. These alarms were recorded in the system historian.

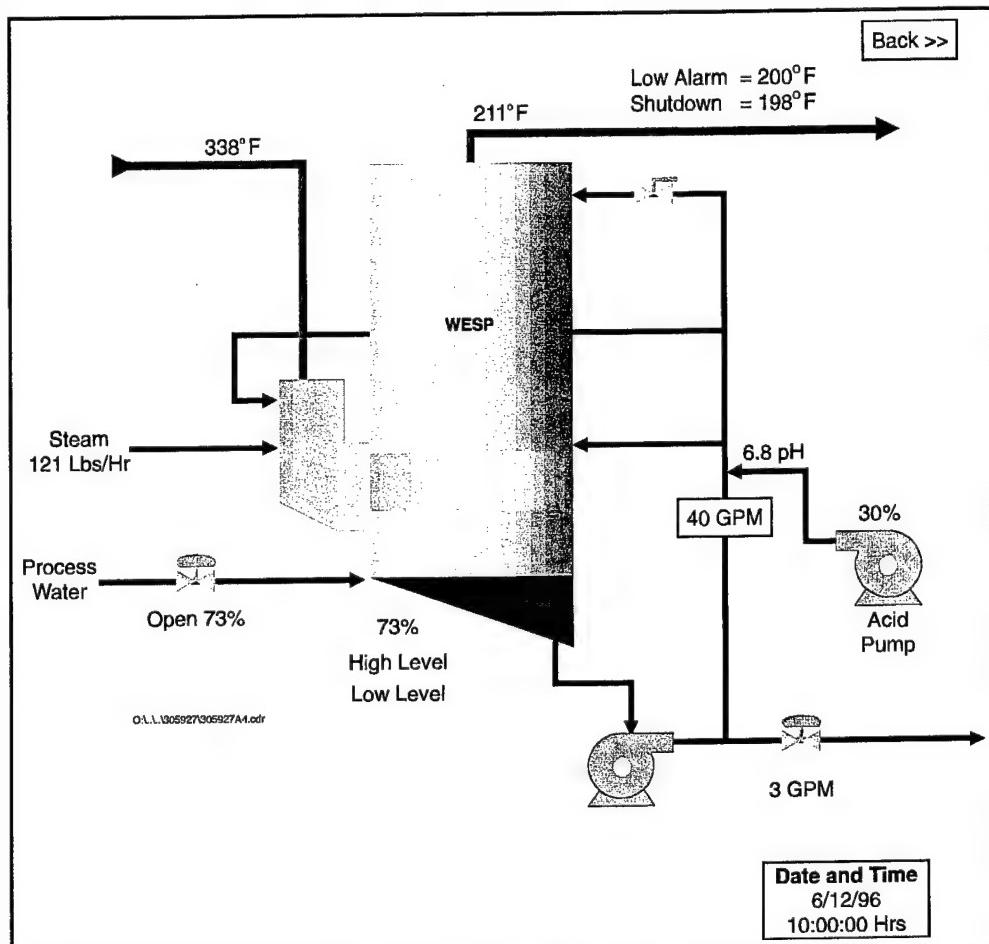


Figure 2-8
WESP Control Screen

The historian stored operating data for the previous four weeks. Table 2-11 shows the different historical screens that were available and the information contained within each screen.

Table 2-11
Historical Instrument Groupings

Flows and Speeds	Kiln Temperatures
F1521 WESP Recycle FI712 Kiln Steam FI714 Steam to WESP SI211 Kiln rpm SI582 ID Fan rpm WI110 Soil Feed Rate	T212A Bed temperature T212B Bed temperature T212C Bed temperature T212D Bed temperature T212E Bed temperature T212F Bed temperature TI811 Ash temperature
Levels	pH
LI524 West Sump Level LI530 Primary Condenser LI552 Scrubber Level LI610 Polymer Tank LI665 Clarified Water Tank LI680 Treated Water Tank LI750 Diesel Fuel Tank	AI526A West Inlet pH AI526B West Outlet pH FI528 West Blowdown Flow
Pressures	Temperatures
PI582 ID Fan Outlet PDI510 Multiclon DP PDI532 Primary Condenser DP PDI54 Scrubber DP PI560 Chiller Condenser Outlet PI581 ID Fan Inlet PI572 HEME DP PI210 Kiln Vacuum	TI510 Kiln Outlet TI512 Cyclone Outlet TI524 West Outlet Temperature TI554 Scrubber Outlet TI502 Stack Temperature TI582 ID Fan Outlet

Figure 2-9 shows the “pressures” screen. This screen spans a period of 24 hours and shows system pressures during that interval. The specific pressures that are displayed are listed at the bottom of the screen. A vertical bar runs across the graph that can be moved. The specific values listed at the bottom of the screen are those values corresponding to the location of the vertical bar.

In Figure 2-9, the numbers in the lower right area give the pressures at the time indicated by the vertical bar (about 20:00 hours). The numbers on the y-axis, however, only correspond to one of the pressures, in this case, kiln vacuum. The user can change the y-axis to apply to any one of the pressures displayed.

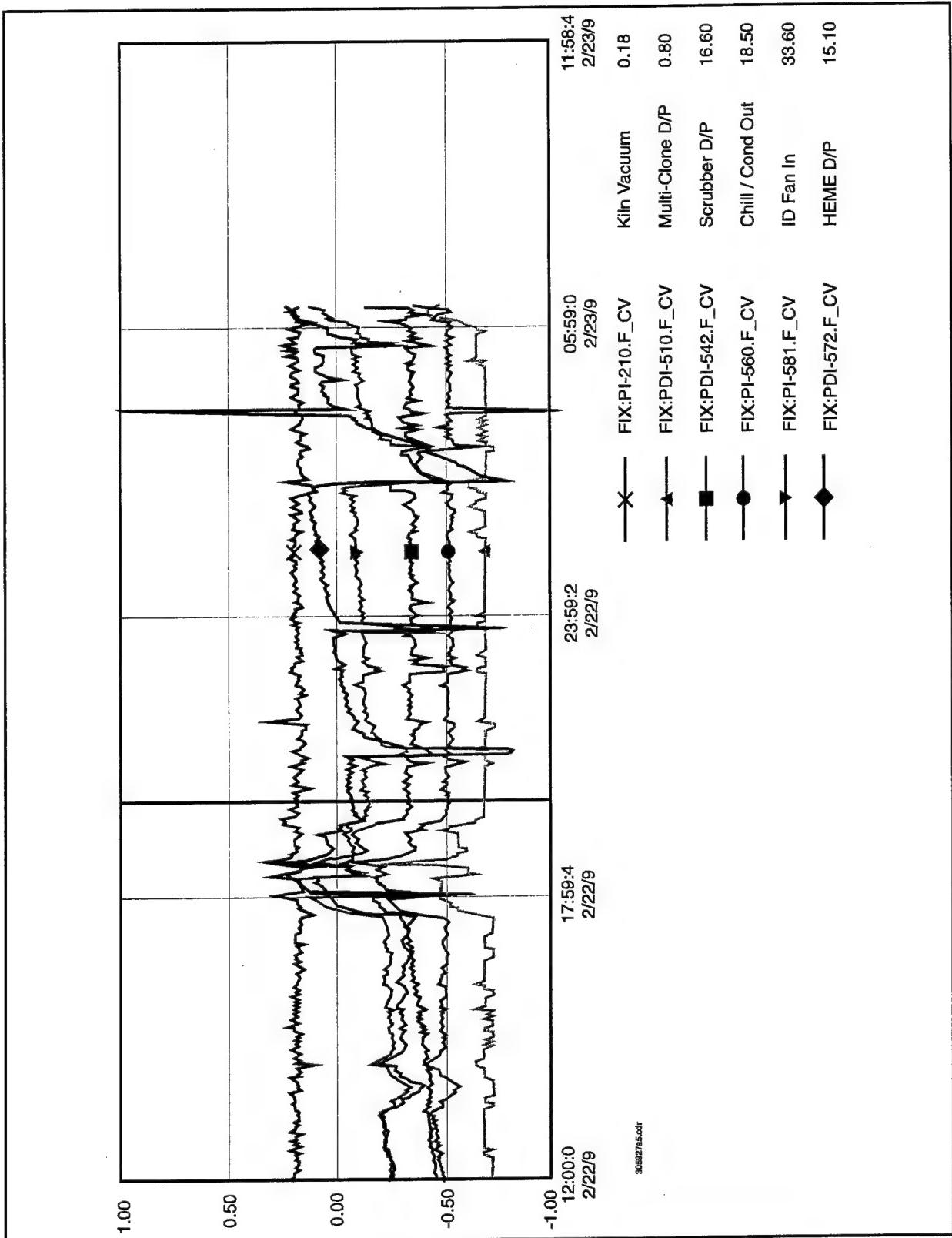


Figure 2-9
Pressures Historical Screen

The user can select to view either a 2-hour or 24-hour interval on the screen. The user can also zoom in on any area of the screen to see more detailed information.

Custom historical screens can easily be created. If the user wishes to see a grouping other than one of those shown in Table 2-11, that grouping can be created and displayed.

The software also stored operating data in a spreadsheet at an interval specified by the user. During the operations on Guam, data were recorded in the spreadsheet every 30 minutes during the operations of the full-scale system. An example of these data are shown in Appendix C.

The historian was used to maintain a record of production and was very valuable in diagnosing equipment operating problems.



3.0 Plant Operation

The BCDP system was operated in two configurations: the rapid start system and the full scale system. These configurations are described in Section 1.3. Except for the Venturi and Bubble Tray Scrubbers, which were not used in the full scale system, all the equipment used in the rapid start system was used in the full scale system.

The rapid start system was not as well documented as the full scale system because the computer data logging system was not yet installed. In the rapid start, operations data were logged manually every hour. A stack test was performed on both systems, and comparing the operation of the two systems provides significant insight into the effectiveness of the equipment.

3.1 Rapid Start System

The rapid start system operated from July 11 to mid-September 1995. The stack test was started immediately after start-up and completed by the end of July. The data logs during the period of the stack test are shown in Appendix B. Figure 3-1 is a Process Flow Diagram (PFD) of the rapid start system. The corresponding material balance is shown in Table 3-1.

3.1.1 Feed Preparation and Rotary Kiln Reactor

The crusher, pug mill, and reactor feed conveyor were outside. A cover was built over the reactor feed conveyor and hopper to protect it from the rain, but wet soil was a continuous problem. Wet soil would build up and plug the crusher, and at times would be wet enough to run off the conveyor belt. Most of the material processed was coral, which is much easier to handle wet than clay and other soils. The coral is soft enough to crush easily, and the fact that the material processed was largely coral helped significantly.

Blocks of consolidated coral were excavated that were too large to go into the crusher. A jack hammer that mounted on the excavator boom was not available at that time, so these large blocks of contaminated coral were stockpiled and processed during the full scale operations when the jack hammer attachment had been procured.

Sodium bicarbonate was added to the pugmill during the rapid start operation, but the amount added was not monitored on a regular basis.

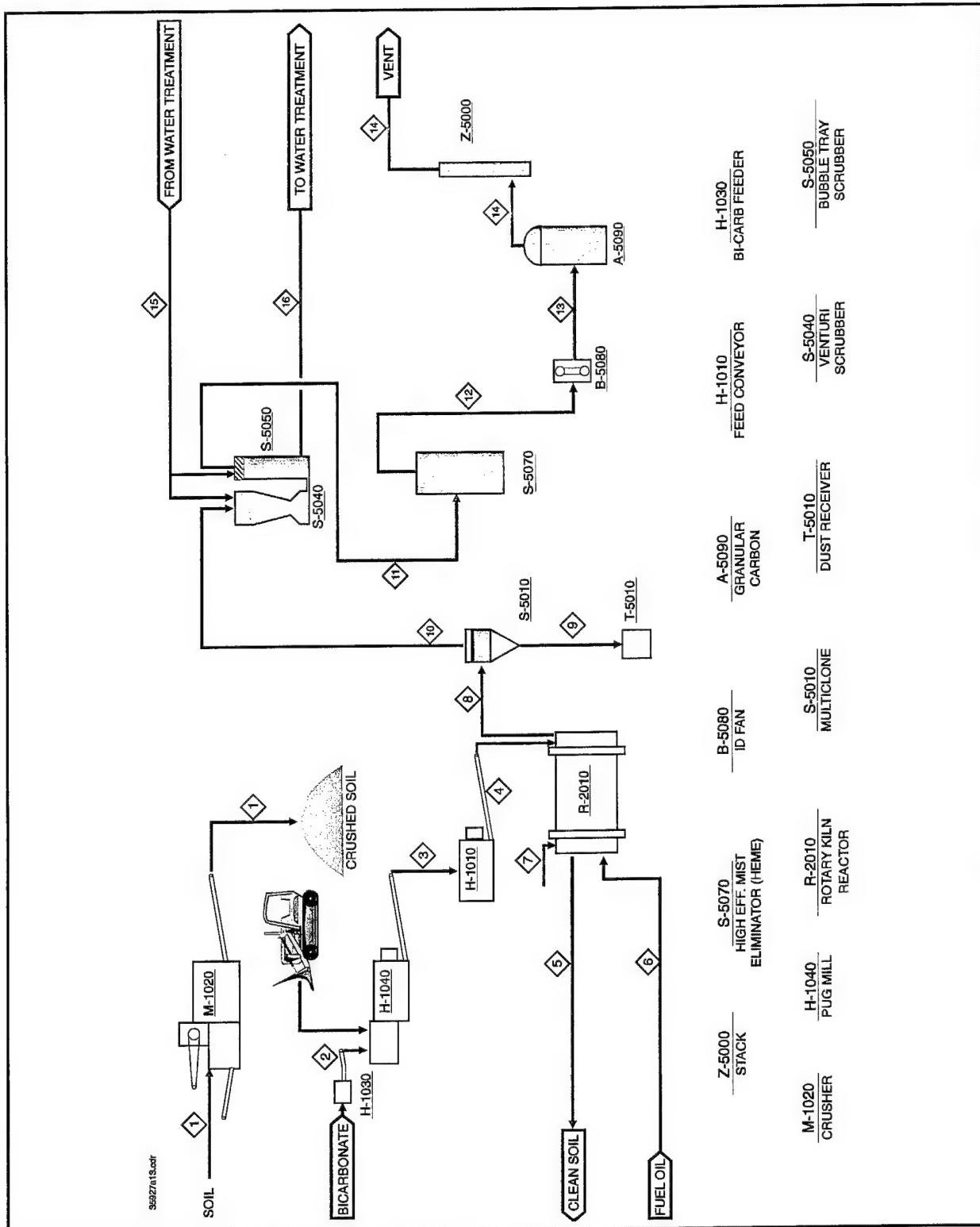


Figure 3-1
Rapid Start System Process Flow Diagram

Table 3-1
Rapid Start System Material Balance

Stream Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Stream Name	Feed Soil	Sodium Bicarbonate	Feed Soil	Reactor Feed	Reactor Product	Fuel Oil to Klin	Sweep Air	Reactor Off-Gas	Multiclon Fines	Multiclon Off-Gas	Scrubber Off-Gas	HEME Off-Gas	ID Fan Outlet	Carbon Off-Gas	Scrubber Water In	Scrubber Water Out
Dry Soil, lbs/hr	37,398		37,398.0	1,2244.0	1,2204.4			3.1	1.6	1.55	0.0775	0				
Percent Moisture	10		10.0	10.0												
Bicarb., lbs/hr		60.0	60.0	2.0												
Sodium Carbonate, lbs/hr				0.6				0.6		0.03						0.03
Water, lbs/hr	4,155		4,155.3	136.0		24.00	160.2		160.2	91.37	66.55	100.39	77.83	9,007.2	9,076.0	
Nitrogen, lbs/hr						865.90	865.9			865.90	865.90	865.90	865.90	865.90		
Oxygen, lbs/hr						261.58	261.6			261.6	261.58	261.58	261.58	261.58		
Carbon Dioxide, lbs/hr						0.5			0.5	0.51	0.51	0.51	0.51	0.51		
Carbon Monoxide, lbs/hr						0.00			0.0	0.00	0.00	0.00	0.00	0.00		
Fuel Oil, gallons per hour					19.5											
Organics, lbs/hr	15	15.0	0.5			0.49	0.00155	0.49		0.25					0.24	
PCB, lbs/hr	30	30.0	1.0			0.98	0.000465	0.98		0.49					0.49	
Degrees F	90	90.0	90.0	560	90	450		240		120.00	110	123	115		120	
Pressure, in. WC gage																
gpm, Normal															18	18
acfM, Normal						260	531		409	312	297	317	304			
lbs/hr, Normal	41,598	60.0	41,658.3	1,363.4	1,221.0	1,127.88	1,293.3	1.6	1,291.3	1,220.2	1,194.5	1,228.4	1,205.8	9,007.2	9,076.8	
lbs/hr, Design Mix																

Notes:
Stack gas is 235 dry standard cubic feet per minute and 0.03 percent CO₂.

Gas is assumed to be water saturated at the temperature indicated.

Organics were measured at the vent stack and PCBs were measured in the feed soil, multiclon fines, and vent stack. Values shown at other locations are assumptions.

The RKR could only be operated at about 0.6 tph because the wet feed would bridge and plug between the two knife gate valves at higher rates. The feed knife gates cycled three times per minute.

The kiln burners were greatly oversized for these slow feed rates. As many of the 14 burners as possible should be operated to provide uniform shell heating, but when all or most of the burners were operated they had to be turned down to their lowest firing point. At very low fire they were unstable and flame outs were common. They also coked up rapidly at low fire and had to be cleaned frequently. The operating technique that evolved to solve these problems was to only operate the four burners that were close to the four zone temperature thermocouples (measuring the temperature on the outside of the shell).

The RKR has a carbon steel shell, and the vendor recommends not exceeding a shell temperature of 1,000°F. Using only four burners, however, the zone temperatures (temperatures outside the shell) were raised to about 1,100°F to insure that the soil would be clean. Since the burners were operated directly below the thermocouples, these zone temperatures should be the hottest point on the shell. Zone temperatures during the rapid start run are shown in Appendix B.

The six thermocouples measuring the temperature inside the shell (Bed Temperatures) read erratically during the rapid start, only working part of the time (the instrument problem was solved by the time the full scale system started). When they did work, only the first five functioned. The bed temperature was typically over 700°F by the second thermocouple, about 10 feet from the soil feed end of the shell. Bed temperatures at thermocouples 4 and 5 were over 800°F and sometimes over 900°F. Producing a reactor product having less than the 2 ppm per PCB congener treatment limit was never a problem.

Sweep air was introduced at the soil discharge end of the kiln through a control valve that could be adjusted from 0 to 100 percent open. The demonstration run used exhaust gases from the kiln stack for sweep gas. Exhaust gases were not used for the production runs because of concerns that hydrocarbons from uncombusted diesel fuel would be drawn into the kiln.

The sweep gas valve was set at 50 percent open. This produced a stack flow of about 300 acfm, or about 230 dry standard cubic feet per minute (dscfm). As shown in Table 3-1, this corresponds to a sweep gas flow of 260 acfm at 90°F. This is a maximum value because it assumes no air infiltration.

tion between the kiln and the stack. The kiln cross section area is 6.7 square feet, so the sweep gas velocity in the hot end of the kiln at 800°F is 1.5 feet per second.

A minimum sweep gas is necessary to remove organics from the kiln as they are cooked off the soil. Sweep gas flows that are higher than this minimum will drag more fines out of the kiln into the APCS. These fines are contaminated and become residuals. No attempt was made during the rapid start to find this minimum velocity.

At each end of the rotating shell, a ware plate on the shell pressed against a stationary plate on the end breaches. The stationary plate was equipped with grease fittings, and a system was added to inject high temperature grease into this seal. Grease injection was also installed for the trunnion bearings. A set of idler trunnions, located at each end of the 30-foot-long shell, supported the entire weight of the shell.

When the kiln off-gas exited the rotating shell and entered the feed breech section, the gas velocity slowed significantly. Gas exited the breech section through a 6-inch duct. Fines dropped out and built up until the breech section was full, except for a pathway between the kiln shell exit and breech exit. As the pathway became smaller, the gas velocity increased until no additional fines dropped out. There was never a gas flow pressure drop increase in this area.

In addition to fines, feed soil also spilled out of the rotating shell into this breech area. At times, material would build up between the rotating shell and the stationary breech and create a drag on the shell rotation. At the end of the rapid start run, a 10-inch gate valve was installed in the bottom of this breech section to drop these fines out. The material collected at this point was returned to the Feed Preparation Building to be recycled into the kiln.

3.1.2 Air Pollution Control System

The rapid start APCS operated acceptably, but it did not achieve the emission reduction of the full scale system. The performance of the rapid start and full scale systems were consistent with the design basis discussed in Section 2.3 of this report.

The APCS, from the kiln to the ID Fan, operates under vacuum to insure that contaminated gases do not escape to the environment. If any leaks occur, air will leak into the system. The actual air infiltration rate was unknown during the design phase of the project, and the initial design of the

APCS assumed an air infiltration rate throughout the APCS that was much greater than what was actually encountered. As a result, the components of the APCS are greatly oversized. Most of the equipment still operated acceptably. The impact of the oversizing on individual equipment items is discussed below. Off-gas ducts were also much bigger than necessary. Where these ducts handled a gas flow high in particulate, particulate settled in the duct until the cross sectional duct area was reduced. This created a velocity high enough to prevent any additional settling. No pressure drop problems were encountered in the gas ducts.

Multicloner. As discussed in the previous section, fines removal from the off-gas started in the RKR soil feed breech. Immediately after exiting the RKR the off-gas passes through a three-cone Multicloner. The Multicloner was insulated and the cone section, where the gas is stagnant, was electrically heat traced. The Multicloner was designed to operate at a pressure drop of 4 inches of water at a gas flow of about 700 acfm. The actual gas flow during the rapid start was about 500 acfm and the Multicloner pressure drop typically ran between one and two inches of water. Although not quantified, the lower-than-design gas flow and pressure drop reduced the fines removal efficiency of the unit.

Fines exiting the Multicloner dropped through a flexible bellows into a 55-gallon drum. A gate valve in the drop out line was normally open and closed when the fines collection drum had to be changed. Since the fines collection rate was less than a drum per day, this system was satisfactory. A rotary valve was later placed on the Multicloner discharge to help insure that no air was leaking up into the Multicloner. Air leakage at the unit's solids discharge port will re-entrain fines and reduce the efficiency of the unit. The rotary valve plugged from time to time and had to be manually cleared.

Venturi and Bubble Tray Scrubbers. From the Multicloner, the off-gas flowed into the Venturi Scrubber and from there immediately into the Bubble Tray Scrubber. The Venturi removed most of the dust remaining in the gas stream and some of the organic aerosols. The removal efficiency of the Venturi increases as the pressure drop increases. Initially, the Venturi was operated at a pressure drop of about 20 inches of water, but after about two weeks that was raised to 40 inches of water. The pressure drop was controlled by manually adjusting the venturi plate in the throat of the scrubber.

Normally, most of the pressure drop in the APCS was caused by the scrubber. The ID Fan was controlled by the kiln vacuum, which was normally set at just under one-half inch of water. When

the kiln soil feed valves plugged, both knife gates were opened so the operator could manually clear the plug. With both valves open, the vacuum in the kiln fell to zero and the ID Fan responded by speeding up. This increase in flow rapidly increased the pressure drop across the Venturi to about 80 inches, and that in turn opened the vacuum relief valve on the ID Fan inlet. An operator would have to manually open the venturi plate to lower the pressure drop back to the control point. When the kiln feed valves were returned to normal operation the Venturi pressure drop was too low until the venturi plate was manually closed. After the rapid start run, a pneumatic throat adjustment was installed on the Venturi to solve this problem. The throat adjusted automatically to maintain a preset pressure drop.

While the throat adjustment allows the Venturi to operate efficiently over a wide range of gas flows, the Bubble Tray Scrubber is not adjustable and has a narrow range of gas flows over which it operates efficiently. Because the system never operated close to the design flow range, the Bubble Tray Scrubber was not effective.

HEME. From the scrubber, the gas flowed to the HEME. The HEME was designed for flows up to 700 acfm, much higher than the flows it normally experienced. The HEME, however, has infinite turndown. In fact, it operates more efficiently at lower flows. If the gas flow exceeds the design rating, it is possible for the gas passing through the HEME to entrain liquid and carry it out in the gas stream. Because the HEME was oversized, this entrainment and carry-over was not a problem.

As aerosols collect in the HEME, they drain to the bottom of the element and then from the element into the HEME tank. During the rapid start, a water seal was used in the drip leg from the HEME element. No significant amount of organics were collected. The water did turn a light brown color, but no free oil, floating or sinking, was detected. Water did condense out of the hot, saturated gas stream leaving the scrubber and accumulated in the HEME tank.

Without the WESP, the bulk of the aerosol removal was done in the HEME. The rapid start system started up on July 11, and the first HEME failure occurred a week later at 2400 hours on July 18. Failure occurs because of a buildup of material in the HEME that plugs the HEME. This buildup is marked by an increase in the pressure drop across the HEME. Even with a pressure drop up to 1 pound per square inch (psi), the HEME is still cleaning gas effectively, but once pressure starts to build, it increases rapidly to a point where it is not practical to continue operating the unit.

Mechanical damage to the HEME element begins when the pressure drop is about 28 inches of water (1 psi) — the fabric starts to tear and implode.

Figure 3-2 is a plot of the gas flow rate and the HEME pressure drop during the first HEME unit's last 90 hours of operation at the beginning of the rapid start run. During the first 5 days of operation, the pressure drop stayed below 10 inches of water. During the 6th day of operation, the pressure drop increased to around 20 inches of water, and on the last day it climbed rapidly to 60 inches. The gas was then switched to a new element, and the pressure drop immediately fell to about 2 inches of water. This general pattern of failure was repeated throughout the rapid start run. The HEME would normally operate at a pressure drop below 10 inches. Once the pressure drop started to increase, the rate of increase would be rapid and failure would occur within a day or two.

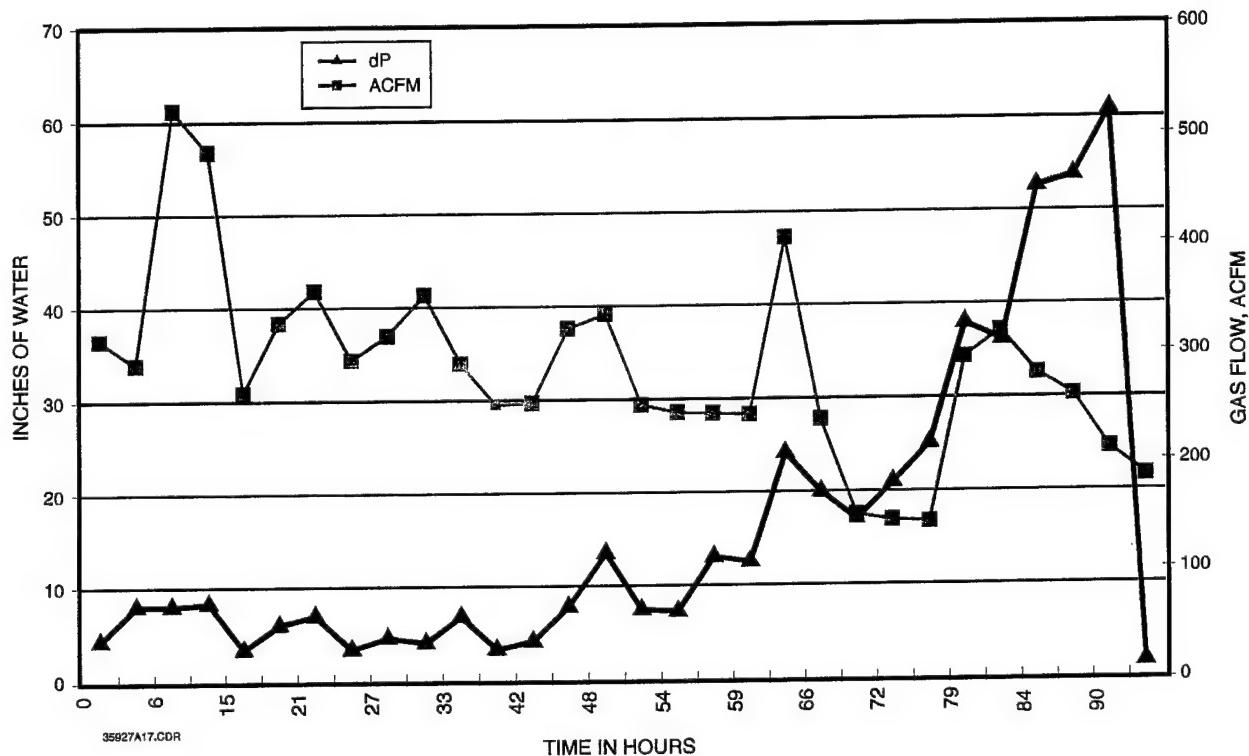


Figure 3-2
Gas Flow Rate and Pressure Drop During the First HEME Unit's Last 90 Hours of Operation
Starting at 0600 Hours on July 14, 1995 (Rapid Start)

Figure 3-2 also shows, as expected, that pressure drop is a function of the gas flow rate through the unit. As the gas flow increases, the pressure drop increases. Flow through the element is laminar,

not turbulent, so the pressure drop should vary linearly with the flow. The last data point on Figure 3-2 was recorded after the off-gas was switched into the new HEME.

HEME elements installed later during the rapid start lasted longer, from two to three weeks. The short life of the first HEME was probably due to the erratic equipment operation that is to be expected during start-up of a first-of-a-kind system. As operating experience was gained, the cyclone and scrubber ran smoother and reduced the load on the HEME. As will be discussed later, once the full scale system with the WESP and steam sweep were installed, HEME life became very long. The full-scale system operated for 10 months with the same HEME and a pressure drop below one inch of water.

Experience with the rapid start system confirmed one of the predicted advantages of the HEME. It provides a secure barrier against the release of contaminated gases. If APCS equipment before the HEME operates poorly, the HEME's life will be shortened, but the gas will still be cleaned. Recall that the rapid start system stack test was performed during the start-up period, with favorable results.

The HEME was covered with a prefilter bag to catch particulate that would otherwise enter and plug the HEME element. The prefilter bag cost \$300 and took two operators about two hours to replace. The element cost \$2,400 and required two operators about 6 hours to replace. These changeouts were done in Level C. It was discovered, however, that replacing the prefilter bag did little to extend the life of the HEME. New bags and elements are white. When the element was pulled from the failed unit, both the outer bag and the element were brown, and the element was brown on both sides, indicating that organics had penetrated the bag and soaked into the element.

The HEME element cage was pulled out of the HEME tank using an electric wench mounted on an I-beam. The I-beam was installed about 7 feet above the roof of the APC building directly over the HEME tanks. A hatch was cut in the roof above the HEME tanks that could be removed to pull an element. The element was pulled straight up to clear the tank, then moved to one side of the tanks and lowered to the floor.

During start-up of the full scale system in March and April 1996, the rapid start configuration was occasionally used because of start-up problems with the new equipment. At that time, the steam boiler was installed and operating. The HEME vendor had reported that they had customers using HEMEs to collect wax mists. When these elements plugged, they were taken off line and heated

with steam. The heat reduced the viscosity of the wax sufficiently for it to drain out of the element. A material's viscosity will determine whether or not it will drain from a HEME. Since the viscosity of the material that would be collected on the BCDP HEME was unknown during the design phase, the flexibility of using steam to clean the HEME was designed into the system by specifying fiberglass elements that could stand temperatures over 200°F. Unfortunately this could not be tried during the rapid start system because there was no source of steam.

In early April, a one-half inch steam hose was run from the boiler to a plugged HEME. All the nozzles on the HEME tank were valved off except for the element drain nozzle at the bottom of the tank. Low pressure (15 psig) steam was injected into the HEME tank through a nozzle near the bottom of the tank. Condensate drained out of the element drain into a bucket. The tank drain valve was opened periodically to drain the tank. These condensates were put into a 55-gallon drum. The condensate from the element was yellow, and the tank condensate was clear. After about an hour, the temperature at the top of the tank reached 206°F and stayed at that temperature. Over a 24-hour period, 42 gallons of condensate were collected in the condensate drum. There was only a slight oil sheen on the surface of the condensate. A sample was analyzed to determine if the liquid could be added into the water treatment plant. The condensate contained low levels of PCBs and biphenyl and was returned to the water treatment plant. It was an oversight that the condensate was not examined for sinking (heavier than water) organics.

The pressure drop across the HEME fell back to its normal operating range after the steaming. A full evaluation of the success of this procedure could not be made because the full scale system came back on-line and operated for the rest of the remediation period. The load on the HEME was so low during full scale operations that no pressure drop increases occurred.

ID Fan. Because of the Venturi Scrubber, the ID Fan drew a much higher vacuum during the rapid start run than during the full scale plant operation. When both RKR knife gate valves were opened to clear a feed plug, the RKR vacuum would drop causing the ID Fan to speed up. This increased gas flow across the throat of the Venturi Scrubber caused the scrubber pressure drop to increase rapidly, damping the effect of the increased Fan speed on the vacuum in the RKR, and sometimes activating the vacuum relief valve on the ID Fan before opening the RKR feed valves.

The solution was to switch the Fan from automatic to manual operation and manually open the Venturi Scrubber throat before opening the feed valves. This allowed the ID Fan to pull a higher

volume of gas without an excessive pressure drop. The increased gas flow was necessary to keep gas from escaping the RKR through the open knife gate valves while they were being cleaned. The Venturi throat was returned to its original setting after the feed valves were returned to normal operation.

No mechanical problems were encountered with the ID Fan; it operated smoothly during the entire rapid start. This rotary lobe fan depends on close clearances between the rotating lobes and fan casing to provide a seal. If any particulate a few thousands of an inch in size or larger were to enter the fan, it would erode the fan at these seal points. No indication of such erosion occurred, indicating that the rapid start APCS was doing a good job of removing these particulate.

Air Carbon Bed. Because the chiller condenser was not available, water continuously condensed and dripped out of the air carbon beds. Drain valves on the bottom of the carbon beds were periodically opened to drain the beds.

At the end of the rapid start run, the air carbon vessels were emptied and sampled. The PCB concentrations in the carbon were:

- Inlet to the first carbon bed 800 ppm
- Inlet to the second carbon bed 12 ppm
- Outlet of the second carbon bed 1.2 ppm

The 12 ppm sample is after the off-gas passed through 600 pounds of carbon, and the 1.2 ppm sample is after the gas passed through the entire 1,200 pounds of carbon. The total quantity of PCBs captured by the carbon can be estimated by assuming that the drop off in concentration is linear (it is obviously much faster than that, so the linear assumption will give a high value for total PCBs in the carbon).

The amount of PCB in the first 600 pounds of carbon is approximately:

$$[(800 + 12)/2] * 10^{-6} * 600 = 0.24 \text{ pounds}$$

The quantity of PCB in the second carbon drum is:

$$[(12 + 1.2)/2] * 10^{-6} * 600 = 0.004 \text{ pounds}$$

During the rapid start run, about 500 tons of soil was processed with an average concentration of 50 ppm PCB, thus the quantity of PCBs removed from the soil during the rapid start was:

$$500 \text{ tons} * 2000 \text{ pounds/ton} * 50 * 10^{-6} = 50 \text{ pounds}$$

The stack test results will be discussed later, but the PCB stack emissions during the rapid start were 776 micrograms per hour. Over a 60-day period this would amount to:

$$776 * 10^6 \text{ grams/hr} * 1 \text{ pound}/454 \text{ grams} * 60 \text{ days} * 24 \text{ hours/day} = 0.02 \text{ pounds of PCB emissions.}$$

Thus out of the 50 pounds of PCB that were driven off the soil, 0.24 pounds (0.5 percent) were removed in the carbon, 0.02 pounds (0.04 percent) escaped in the stack gas, and the remaining 49.74 pounds (99.5 percent) were either destroyed or removed before the carbon.

The carbon, as designed, was for final polishing, and most PCB removal occurred in the APCS prior to the carbon. The soil treated during the rapid start was relatively low in PCB. As explained in the APCS design theory (Section 2.3), higher concentrations of PCB in the soil should result in greater PCB condensation and a higher percentage removal in the APCS prior to the carbon.

3.1.3 Wastewater Treatment Plant

The rapid start WWTP was similar to the full scale system, but the clarifier and variable speed flocculation mixer were not yet installed. Wastewater was fed directly to Tank S6020 (Appendix A), and the surge tank was used as the clarifier. Wastewater was introduced into one end of the surge tank, and the clarified water was pumped out at the other end of the tank.

An agitator from the demonstration plant was used in the flocculation tank, but the agitator was a constant speed unit and its speed was too high to create a good floc. A good floc could be achieved in the laboratory. Most of the floc settled well, but some floc stayed in suspension, apparently because of low levels of light, non-water soluble organics attached to some of the particulate. Acid addition to samples in the laboratory to drop the pH from 8 to 6 would sometimes create an oil sheen

on the surface of the sample, indicating that oil was bound in the water as an emulsion. A pH adjustment and decant system was later added to the water entering the WWTP, but no oil was ever separated. Lowering the pH to around 6 did appear to aid settling.

Although most of the solids settled in the clarifier, enough passed through the clarifier to slowly plug the carbon vessels. Most of the water was recirculated from the clarifier directly back to the scrubber. The water took on a brown color and developed a distinctive organic odor, indicating that soluble organics were building up in the water. This same odor had been detected during the demonstration runs.

Initially, treated water was accumulated in day tanks and tested prior to discharge to the sanitary sewer. The treatment limit was 1 part per billion (ppb) PCB. Although levels below 5 ppb were attainable without great difficulty, the 1 ppb limit was not easily achieved. This problem was solved by spraying the water on the reactor product for cooling and dust suppression to eliminate the water discharge.

3.1.4 Rapid Start Stack Test Results

The rapid start stack test was conducted from July 13 to July 23, 1995, immediately after the July 11 start-up. The complete stack test report is shown in Appendix E, and the plant operating conditions during the stack test are in Appendix B.

A discussion of hazardous waste incinerator emission limits and guidelines on comparing BCDP emissions to incinerator emissions are provided in Section 3.2.4.

PCB Emissions. The PCB concentration in the stack gas was 2.74 micrograms per cubic meter with a mass emission rate of 776 micrograms per hour. The stack flow was 210 acfm (167 dscfm) at 111°F.

These actual PCB emissions can be compared to the predicted emissions as calculated in Section 2.3.1. Using the regression equation from Section 2.3.1, the vapor pressure of Arochlor 1260 at 111°F is:

$$p = \exp(-14921.6 * (1/(111+460)) + 15.00) = 1.46 * 10^{-5} \text{ psia}$$

The gas is water saturated, and at 111°F will contain 0.061 pounds of water per pound of dry air. Based on 100 pounds of gas, the mole fraction water can be calculated.

$$\text{Pounds of water} = 100 * 0.061 = 6.1 \text{ pounds}$$
$$\text{Pounds of air} = 100 - 6.1 = 93.9 \text{ pounds}$$

$$\text{Moles of water} = 6.1/18 = 0.339$$
$$\text{Moles of air} = 93.9/29 = 3.24$$

$$\text{Mole fraction water} = 0.339/(0.339 + 3.24) = 0.0947$$

The molecular weights of water, air, and Arochlor 1260 are 18, 29, and 352, respectively. The weight fraction of PCB in the gas is calculated as follows:

Basis: 100 moles

$$100 * 1.46 * 10^{-5}/14.696 = 9.93 * 10^{-5} \text{ moles of PCB}$$
$$100 - 0.000146 = 99.999854 \text{ moles of water and air}$$
$$99.999854 * (1 - 0.0948) = 90.52 \text{ moles of air}$$
$$99.999854 * 0.0948 = 9.48 \text{ moles of water}$$

$$\text{Pounds of PCB} = 9.93 * 10^{-5} * 352 = 0.035 \text{ pounds}$$
$$\text{Pounds of air} = 90.52 * 29 = 2,625 \text{ pounds}$$
$$\text{Pounds of water} = 9.48 * 18 = 170.6 \text{ pounds}$$
$$\text{Total pounds of gas} = 0.035 + 2625 + 170.6 = 2795.64$$

The predicted weight fraction of PCB in the gas during the stack test is:

$$0.035/2795.64 = 1.25 * 10^{-5} \text{ pounds PCB/pound gas}$$

The actual PCB concentration in the stack gas was 2.74 micrograms per cubic meter. One cubic meter contains 35.31 cubic feet, and one pound mole of gas at 32°F and one atmosphere occupies 359 cubic feet. At 111°F a pound mole of gas occupies:

$$359 * ((111 + 460)/(32 + 460)) = 416.6 \text{ cubic feet}$$

The density of the gas is:

$$2795.65/100 = 27.95 \text{ pounds/mole}$$

$$(27.95 \text{ pounds/mole})/(416.6 \text{ ft}^3/\text{mole}) = 0.0671 \text{ pounds per cubic foot}$$

A cubic meter of this gas would weigh:

$$0.0671 \text{ pounds/ft}^3 * 35.31 \text{ ft}^3/\text{m}^3 = 2.37 \text{ pounds per cubic meter}$$

The PCB in a cubic meter of stack gas was measured at:

$$(2.74 * 10^{-6} \text{ grams/m}^3)/(454 \text{ grams/pound}) = 6.04 * 10^{-9} \text{ pounds per cubic meter}$$

Thus, the PCB concentration in the stack gas was:

$$(6.04 * 10^{-9} \text{ lbs/m}^3)/(2.37 \text{ lbs/m}^3) = 2.55 * 10^{-9} \text{ pounds PCB/pound gas}$$

The measured concentration is 4,900 times less than the predicted concentration, $1.25 * 10^{-5}$ pounds PCB per pound gas. There are two possible reasons for this difference: the theoretical model does not include the carbon, which removed PCBs prior to the stack, and the APCS equipment may remove PCBs at a higher rate than predicted (for example, by the solubilization of PCB vapor in other organics). Some insight can be gained by considering mass emissions.

The stack flow was 210 acfm, so the predicted PCB mass emission rate was:

$$\begin{aligned} 210 \text{ acfm} * 60 \text{ minutes/hour} * 0.0671 \text{ lbs/ft}^3 * 1.25 * 10^{-5} \text{ pounds PCB/pound gas} \\ = 0.01057 \text{ pounds PCB per hour} \end{aligned}$$

The measured mass emission rate was:

$$\begin{aligned} 210 \text{ acfm} * 60 \text{ minutes/hour} * 0.0671 \text{ lbs/ft}^3 * 2.55 * 10^{-9} \text{ pounds PCB/pound gas} \\ = 2.16 * 10^{-6} \text{ pounds PCB per hour} \end{aligned}$$

Over the 60-day period of the rapid start, the total unexplained PCB removal is:

$$60 \text{ days} * 24 \text{ hours/day} * (0.01057 - 2.16 * 10^{-6}) \text{ pounds PCB/hour} = 15.2 \text{ pounds PCB}$$

This is well above the 0.25 pounds of PCB that was found in the carbon at the end of the rapid start run. It would appear that the APCS removes significant quantities of PCBs by methods other than vapor condensation.

Dioxin Furan Emissions. The average TEQ dioxin/furan concentration in the stack was 2.15 nanograms per cubic meter with an average stack gas flow of 275 dscfm.

Hydrochloric Acid Emissions. Hydrochloric acid concentration in the stack gas was 0.057 grams per cubic meter with a stack gas flow of 159 dscfm. Mass emissions were 15 grams per hour.

Volatile and Semivolatile Emissions. Semivolatile emissions were insignificant. The total volatiles concentration detected in a Summa canister grab sample were 8 ppm. The largest concentrations were propylene, 4 ppm, and acetone, 2.8 ppm. Benzene was present at 0.34 ppm. For comparison purposes, the OSHA Permissible Exposure Limit for benzene is 1.0 ppm (time weighted average for breathing air in a workplace).

3.1.5 Treatment of High Organic Soils and KPEG Residuals

The soil treated during the rapid start run averaged 50 ppm PCB and was coral with a very low organic content. Two tests of high organic material were made during these runs. The first test was to feed soil that was high in organic and PCB content to the kiln for about 8 hours. The second test consisted of feeding residuals from the 1988 KPEG operations for about 8 hours. These residuals were PCB free, but they contained high organic soil mixed with 400 molecular weight PEG.

As discussed previously, the off-gas can be viewed through a plexiglass plate that is bolted over an access hatch on the Bubble Tray Scrubber. When coral was processed, the off-gas at this point could not be seen — the gas was clear. When the high organic soil and KPEG soil were processed, the off-gas had the appearance of a dense, white fog. When a focused beam of light from a 6-volt flashlight was directed through the plexiglass, the beam was clearly visible, although the back of the scrubber vessel (about 2 feet away) was not visible.

This observation is consistent with the theory that organic aerosols are created when organics are cooked off of the soil in the kiln. The coral was so low in organics that it did not release a visible "fog." The high organic material did release an aerosol of micron size organics. When a focused beam of light is passed through an aerosol, the beam is visible because the micron size particles scatter the light. This is known as the Tyndall effect. During the full scale operation, this test was used to evaluate the operation of the WESP during the treatment of high organic soil. When the WESP was operating well, the off-gas was clear and the light beam was invisible. When the WESP was down, or operating at low voltage because of some upset, the light beam was visible.

An oil sheen developed on the wastewater indicating that the Venturi Scrubber was removing some of the organics. The HEME pressure drop increased several inches, then returned to normal several hours after the high organic run was finished. This is consistent with the operating theory of the HEME — organics are collected in the fabric and then drain to the bottom of the HEME element.

3.2 Full Scale System

The full scale system operated just over a year, from April 1996 to May 1997.

Appendix A contains the Plot Plan, P&IDs, and the PFDs for the full scale system. The Plot Plan is a scale drawing of the process area and provides dimensions for the buildings, equipment, and other physical components at the BCDP site. The P&IDs contain detailed system information including the size and material of construction of the equipment, piping, pipe fittings, instrument locations, etc. The flow rate, composition, temperature, and pressure of material flows in each step of the process is provided in the PFDs.

A sample of operating data from the data logger is shown in Appendix C.

3.2.1 Feed Preparation and Rotary Kiln Reactor

Soil Excavation and Handling. The excavation plan is part of the work plan. Excavation was performed with a track excavator with a 1.25 cubic yard bucket. A jack hammer attachment was available that could be mounted on the end of the excavator boom to break up coral. Consolidated coral was excavated by using the hammer to break up a layer of the coral. The jack hammer was then changed out for the bucket and the coral was picked up.

A five-ton dump truck was used to haul contaminated soil from the excavation area to the soil conditioning area behind the Feed Preparation Building. The truck was decontaminated at the end of each day when it was used to haul contaminated soil. Because the Guam BCDP was a small unit, excavation was much faster than soil processing, and only occurred a few days each month.

Excavated material was stockpiled behind the Feed Preparation Building. If the material was too wet to crush, it was spread out on the ground on sunny days and turned every half to one hour using a track loader with a 2.5 cubic yard bucket. The loader would drag the soil with the bucket teeth. If this were a larger site, the soil could have been turned more efficiently with a set of disks. A rubber-tire loader was initially used to work the soil, but the sharp coral damaged the tires and forced the change to a track loader.

Soil moisture was the most important factor effecting production. Wet soil could not be crushed because it would plug the crusher. For periods lasting several days or weeks at a time, the RKR was run at rates under 1 tph because there was not sufficient dry soil to crush.

A two cubic yard rubber-tire front-end loader was dedicated for use inside the Feed Preparation Building. This loader hauled material between the soil stockpile area and the building and loaded the crusher and RKR feed hopper.

A rubber-tire front-end loader was used for clean work such as moving the reactor product from the product storage bins to the treated soil stockpile area. The dump truck was also decontaminated and used to haul treated soil as necessary.

A small rubber-tire loader that could be equipped with either forks or a half cubic yard bucket was used to move equipment, pallets, and drums of residuals.

Feed Preparation Building. The Feed Preparation Building housed the crusher and RKR feed hopper. The Pug Mill was not used in the full scale system. The sodium bicarbonate was added to the soil as it traveled up the conveyor belt to the RKR and mixed with the soil in the RKR.

The Feed Preparation Building was the only Level C (respirator and tyvek) area in the plant. Normally, two operators would be required in the Feed Preparation Building for safety reasons. A pan and zoom camera was mounted inside the building above the roll-up door that could monitor

the activities inside the building. The camera transmitted to a monitor in the control room. This allowed an operator to work alone in the building while his activities were monitored from the control room.

A second camera was mounted over the RKR feed hopper so the control room operator could see the soil level in the hopper. The camera would also show if the hopper was bridging or plugging. A vibrator on the side of the hopper could be activated from the control room to free a hopper plug.

The RKR feed hopper initially held five cubic yards. The bucket on the front-end loader used in the Feed Preparation Building was wider than the hopper and would spill material when dumping into the hopper. Plywood was used to build up and widen the walls of the hopper and increase the capacity to about nine cubic yards. To insure that the hopper never ran empty while the RKR operated, the hopper was never allowed to fall much below half full.

Rotary Kiln Reactor. The RKR performed well during the remediation period. There were periodic problems with soil working between the feed breech and the rotating shell. This created friction on the rotating shell forcing the unit to be shut down so the breech could be opened and the soil cleaned out.

The soil drop chute installed at the bottom of the feed breech between the rapid start and full scale runs worked well and helped to minimize the soil buildup problem. Feed soil and fines from the feed breech were collected in a 55-gallon drum and recycled to the Feed Preparation Building and mixed with the RKR feed soil. The rate at which this material accumulated varied from two or three times a day to less than once a day, depending on the soil being processed and how the RKR was operated. At rates of one tph or less, very little feed soil was collected. As feed rates were taken higher, more feed soil spilled into the breech.

The BCDP's capacity was determined by the RKR operating rate. Table 3-2 shows the monthly average system production rate and on-line percent during the full scale system operation. The Tons per Hour is the average processing rate while the plant ran during the month, and the On-Line Percent is the percent of time during the month that the plant operated.

Table 3-2
Operating Rate and On-Line Percent During Full Scale Operations

Month	Tons Per Hour	On-Line Percent	Tons Produced
April, 1996	1.12	93%	719
May	1.63	85%	1032
June	1.85	81%	1085
July	1.28	76%	729
August	1.04	96%	742
September	1.22	64%	564
October	0.93	98%	674
November	1.00	32%	232
December	1.45	91%	989
January, 1997	1.25	90%	843
February	1.54	93%	963
March	1.43	95%	1009
April	1.72	68%	849
May 6, 1997	2.23	90%	336

Rates were low in April because the system was still having start-up problems. May and June production was high, then the rates fell off from July through November. These are the rainy season months, and rates were reduced because there was a shortage of dry feed. November was an especially bad month. A typhoon hit Guam, and the plant was shut down for the storm and then for repairing storm damage. A scheduled maintenance outage also occurred during this period. As soon as the plant started up, the variable speed drive on the RKR shell motor failed and a new controller had to be ordered from the mainland. It took almost a week to get the controller ordered and shipped to Guam.

The RKR diesel burners were oversized, even at rates approaching 2 tons per hour. The four zones were typically operated at or slightly above 1,100°F. Although operating instructions for the RKR warned against operating the zones above 1,000°F, the extended operation at higher temperatures did not cause a problem. The danger of operating too hot is that the shell, which is only supported at each end of its 30 foot length, can weaken and physically sag.

3.2.2 Air Pollution Control System

The full scale APCS achieved much lower emissions than the rapid start system.

Like the rapid start system, the full scale system operated under vacuum from the RKR to the carbon, and air infiltration rates were much lower than predicted. Gas flows were much lower than predicted. Except for the Venturi Scrubber, which was not used, the equipment in the rapid start APCS was used in the full scale APCS. During the rapid start, the Venturi Scrubber was operated at a pressure drop of about 40 inches of water. Without this unit in the full scale system, the highest vacuum in the system was about 6 inches of water. Although it cannot be quantified, the reduced vacuum would have reduced any air infiltration at leak points.

Multicloner. The multicloner operated even less efficiently in the full scale system than in the rapid start because of lower gas flows. The pressure drop was typically below one inch of water, compared to the design of four inches. The pressure taps plugged frequently and had to be manually opened. This is not an uncommon problem, and should be kept in mind when looking at the pressure drop on the data logs.

The quantity of multicloner fines generated during the remediation is given in the residuals discussion at the end of this section.

WESP. The RKR off-gas enters the WESP at the quench unit, mounted on the side of the WESP. In the quench, water recirculating from the WESP sump is sprayed into the off-gas to water saturate the gas. Since the pressure is close to one atmosphere, the temperature will be at or below 212°F when saturation occurs.

Steam is also injected into the quench section. The steam flow rate is controlled by the WESP outlet gas temperature. As explained in Section 2.3.2, the objective is to maintain a water saturated gas in the WESP at a high enough temperature (above 198°F) so that the oxygen content will be too low to support combustion.

Water from the WESP sump was continuously recirculated to the quench nozzles and to the nozzles below the WESP tubes. A blowdown from this recirculation water went to the WWTP. A level controller in the WESP sump opened a solenoid valve to add make-up water to the sump as needed to maintain the level.

When the plant started up, the WESP blowdown was one gpm. At this blowdown rate, under 100 pounds per hour of steam was required to maintain the WESP temperature. The blowdown was

increased over the following months to reduce the solids level in the WESP. At a blowdown of around 10 gpm, 400 to 500 pounds per hour of steam was required to maintain the WESP temperature because the higher blowdown increased the flow of ambient temperature make-up water to the WESP. The hot blowdown increased the temperature of the WWTP and an air cooled heat exchanger from the demonstration plant was installed to cool the blowdown.

Solids built up in the sump of the WESP requiring the WESP be taken off line and cleaned. This could be done without shutting down the plant by pumping the WESP sump down and flushing the sump with process or fresh water. During a standard maintenance shutdown, the WESP would be opened up and the sump completely cleaned out. The increased blowdown allowed the WESP to be kept on line several weeks at a time between cleanings.

The solids eroded the spray nozzles in the WESP causing them to be replaced once during the operations. The nozzles would also be plugged by the solids requiring the nozzle headers to be removed and cleaned during a system shutdown. During a maintenance shutdown, spray nozzles would be visually checked to see if any were plugged. Two Y strainers in parallel were installed in the WESP pump discharge in November 1996. These helped some by removing the larger particles from the water going to the spray nozzles.

The deluge wash system that sprayed down on top of the WESP tubes worked well, and was used a couple of times a month.

A black coating slowly built up on the WESP insulators during operation. This had to be physically cleaned off during a plant shutdown.

The WESP normally operated around 14,000 to 16,000 volts with a spark every 4 to 7 seconds. The highest voltage recorded was 20,000 volts. Excessive solids buildup inside the WESP or a buildup on the insulators caused the voltage to drop.

The first WESP recirculation pump was a chemical seal diaphragm pump. This pump had two diaphragms on each side of the pump separated by a colored liquid. A sight glass connected to the liquid filled area between the diaphragms allowed the operator to view the liquid. If the diaphragm on the air side of the pump failed, the liquid would be blown out. If the liquid side diaphragm failed,

the liquid would mix with the fluid being pumped and change color. A diaphragm failure would thus be visible to the operator.

A diaphragm pump was selected initially for two reasons. First, it was thought that the liquid coming out of the WESP would contain insoluble oils, and a low shear pump was desired to minimize the chance that an emulsion would form. The second reason is that there is very little NPSH available because of the high temperature of the water leaving the WESP. Diaphragm pumps have low NPSH requirements.

The chemical seal diaphragm pump was selected because a diaphragm rupture is a common failure mode for these pumps. A standard diaphragm pump has one diaphragm with the liquid being pumped on one side and compressed air on the other side. If the diaphragm ruptures, compressed air will be blown into the liquid side of the pump. In this application, that would result in air being blown into the WESP and possibly creating an explosive atmosphere. The chemical seal pump provides a warning if one diaphragm fails, and the pump can be shut down and repaired before the second diaphragm fails.

Operating experience with these pumps was very poor. The teflon diaphragms used on the fluid side of the pump failed within hours after start-up. The pump was tried two more times with the same results. The diaphragms were returned to the vendor, but no reason for their failure could be identified.

A standard diaphragm pump with a neoprene diaphragm was used for most of the BCDP operation. These pumps were still high maintenance, but would operate for weeks at a time between failure. Even though at times compressed air was probably blown into the WESP at the point of failure, there was never any sign that combustion occurred in the WESP. One safety factor was the automatic WESP power shut off at low WESP recirculation flow. A diaphragm failure would drop the pump output low enough to remove the spark (ignition source) from the WESP.

In an attempt to find a lower maintenance WESP pump, a progressing cavity pump was installed in November 1996. This pump operated for a month and a half, but cavitated most of the time generating severe vibrations in the discharge piping. When the liquid being pumped was at ambient temperature, the pump operated very smoothly, but as the WESP was brought up to operating temperature, the vibrations would start. For brief periods (several hours) at a time the pump would

operate smoothly, then start cavitating again. No explanation for these periods of smooth operation was found.

After a month and a half of operation the progressing cavity pump failed mechanically (caused by the cavitation) and the pump was replaced with a standard diaphragm pump. If the cavitation problem is solved, the progressing cavity pump is probably the best choice. A plan for eliminating the cavitation problem is provided in Section 6.0 of this report.

Before the WESP was started up, a decanter was built and installed in the WESP sump that covered about 20 percent of the footprint of the sump. Part of the water falling off the tubes would pass through the decanter and any floating or sinking material would be separated. Two pipes were run from the decanter through the wall of the WESP, one to decant sinking oils and one to decant floating oil. No oil was ever recovered, and the decanter filled with solids after a few weeks of operation.

WESP Safety System. An event occurred on September 9, 1996 that tested the WESP safety systems. The bottom of the kiln feed breech section has a 10-inch knife gate valve that is opened periodically to remove fines that collect in the breech. A 55-gallon drum is connected to this valve when it opens to collect the fines and provide a seal.

On September 9, 1996, this valve was opened at 0520 hours and left open until 0622 hours. No drum was in place to provide a seal. The system's response and recovery, shown in Table 3-3, was reconstructed using the control system historian.

Table 3-3 BCDP Operation Between 0520 and 0645 Hours on September 9, 1996						
Time	Ibs/hr WESP Steam	WESP Outlet Temperature	Fan (rpm)	Fan in Water	Kiln Exit Temperature	Cyclone Exit Temperature
520	256	205	255	5	366	302
525	279	205	260	5	367	302
530	326	204	322	7	359	302
535	387	204	364	9	357	301
540	391	203	404	10	355	301
545	407	202	445	12	353	300

Table 3-3
BCDP Operation Between 0520 and 0645 Hours on September 9, 1996

Time	Ibs/hr WESP Steam	WESP Outlet Temperature	Fan (rpm)	Fan in Water	Kiln Exit Temperature	Cyclone Exit Temperature
550	422	202	484	14	347	297
555	433	201	521	16	342	295
600	388	200	556	17	335	294
605	404	198	594	19	334	292
610	420	198	629	21	330	291
615	432	197	641	23	328	289
620	444	197	641	24	324	287
625	410	198	596	20	355	289
630	402	198	535	17	358	294
635	420	199	501	14	364	296
640	432	200	477	13	369	297
645	439	201	439	12	371	297

Notes: Kiln sweep stream was 105 pounds per hour.

Feed rate was 3,000 pounds per hour.

Feed is typically 10 percent moisture.

When the valve opened, the kiln vacuum which normally runs at about 0.4 inches of water, fell to zero and stayed between zero and a few hundredths of an inch of water vacuum. As soon as the vacuum was lost, the ID Fan automatically responded by speeding up to recover the vacuum. The ID Fan's response to any change in kiln vacuum is greatly damped. If the Fan is not damped, the rapid responses to changes in kiln vacuum will result in continuous over-correction by the Fan and create an unstable control condition.

The ID Fan speed steadily increased from 255 rpm to 641 rpm over a period of one hour. The kiln exit temperature dropped steadily over this hour because the kiln off-gas was being diluted with increasing amounts of outside air as the Fan speed increased. The WESP outlet gas temperature dropped, and as it dropped, the steam injection to the WESP increased from 256 to 444 pounds per hour. WESP steam injection rate automatically varies to maintain a set point temperature in the WESP outlet gas.

Twenty minutes into the event the WESP outlet temperature fell to 203°F and the low temperature alarm sounded. Forty-five minutes into the event the WESP outlet gas temperature reached 198°F and power to the WESP automatically shut down. At 0622 hours, the valve was closed and the system began to return to normal operating conditions.

Table 3-4 shows gas flows and oxygen concentrations in the WESP during this period. The stack flow meter was not operational during this period, so gas flow at the ID Fan was calculated from the pressure drop. Based on stack test data, at a pressure drop of 5 inches the Fan flows 17 standard cubic feet per minute (scfm). The flow was assumed to vary with the square root of the pressure drop ratio, i.e., at a pressure drop of 23 inches the flow is:

$$17 * (23/17)^{0.5} = 20 \text{ scfm.}$$

**Table 3-4
Infiltration Air Flow and Oxygen Content of the Gas Entering and Leaving the WESP**

Time	Fan (scfm)	Infiltration Air (scfm)	Steam (Moles/Min)	Air (Moles/Min)	Oxygen % Based On Flow	Oxygen % Based on WESP Temperature
520	17	0	0.61	0.04	0.68	2.14
525	17	0	0.63	0.04	0.66	2.14
530	20	3	0.68	0.06	0.95	2.48
535	23	6	0.73	0.06	1.07	2.48
540	24	7	0.74	0.07	1.15	2.82
545	27	10	0.75	0.07	1.29	3.16
550	29	12	0.77	0.08	1.40	3.16
555	31	14	0.78	0.08	1.15	3.50
600	32	15	0.73	0.09	1.65	3.84
605	34	17	0.75	0.09	1.74	4.52
610	35	18	0.76	0.10	1.81	4.52
615	37	20	0.78	0.10	1.89	4.86
620	38	21	0.79	0.10	1.91	4.86
625	34	17	0.75	0.09	1.78	4.52
630	32	15	0.75	0.09	1.62	4.52
635	29	12	0.76	0.08	1.41	4.18
640	28	11	0.78	0.08	1.32	3.84
645	27	10	0.78	0.07	1.24	3.50

Flow above 17 scfm was assumed to be infiltration air. Thus a Fan flow of 20 scfm implies $20 - 17 = 3$ scfm of infiltration air. Infiltration air was also calculated based on the drop in kiln exit gas temperature and the results were similar to the flows shown in Table 3-4.

Oxygen percentage based on flow was calculated using the following information:

1. The oxygen content of the 17 scfm from the kiln is 10 percent based on the stack test.
2. Infiltration air is 21.9 percent oxygen.
3. Sweep steam flow was steady at 105 pounds per hour, 300 pounds per hour of water comes off the soil, and the WESP injection steam makes up the balance of the steam.

This oxygen percentage is shown in Table 3-4, along with the predicted oxygen temperature based on WESP outlet temperature.

The calculation of oxygen content based on flow assumes that no steam condensed in the WESP. This case shows oxygen content raising from 0.68 percent to 1.91 percent. Oxygen content based on saturation temperature shows a rise from 2.14 percent to 4.86 percent. Both sets of numbers indicate that oxygen levels were never high enough to form an explosive mixture during the event.

As a final sanity check on the numbers, there are four data points in Table 3-3 where the WESP outlet temperature is 198°F. The average steam flow for these points is 409 pounds per hour and the average calculated infiltration air is 16.75 scfm. At 198°F, air requires 1.92 pounds of water per pound of air to saturate. A 16.75 scfm flow is 1.28 pounds a minute, and this air would pick up $1.92 * 1.28 = 2.45$ pounds per minute of water vapor via the steam. The observed increase in steam flow is $(409 - 256)/60 = 2.55$ pounds per minute. Again, the numbers agree with the design concepts.

The safety system to protect against leaks worked as designed. The damped ID Fan provides ample time for the system to react if a leak should occur.

Primary Condenser. The Primary Condenser operated well throughout the remediation. The only maintenance required was to pressure wash the tubes every few months. This was really preventative maintenance since the outlet gas temperature never rose above 85°F. The cooling tower

water inlet was consistently between 75°F and 80°F, and the cooling tower water outlet ran between 85°F and 90°F. The flow was not measured.

If the WESP had operated better, the Primary Condenser would have stayed cleaner. When the WESP is operating properly, almost no solids should be entering the Primary Condenser. With good WESP operation the condensate leaving the Primary Condenser was clear with no visible signs of solids.

Chiller Condenser. The Chiller Condenser operated well from the start-up until July 1996, when the compressor failed. The failure was caused by a leak in the ethylene glycol solution/freon heat exchanger. This leak allowed water to enter the compressor and the water caused the compressor failure. The replacement compressor and heat exchanger coils (which were replaced under warranty) were not received until January 1997. Since we were close to the end of the project and the repair would cost over \$6,000, the unit was not repaired.

The Chiller Condenser dropped the off-gas temperature to between 40°F and 50°F. Most of the water in the gas was removed in the Primary Condenser, and very little additional water was removed in the Chiller Condenser.

HEME. The HEMEs operated well with almost no maintenance during the full scale operation. The combination of a clean feed gas from the WESP combined with a much lower gas flow kept the HEME pressure below one psi during the full scale production run from April 1996 to March 1997. Initially, the pressure drop was a few tenths of an inch. By the end of the production run, 11 months later, it was approaching one inch.

No liquids were collected in the HEME until the Chiller Condenser failed in July. After that, water collected in the unit at a rate of less than a gallon a day. The water was transferred to the WWTP.

Induced Draft Fan. Other than being oversized, the ID Fan operated without any problems. When the full scale system started up, a valve was cracked to bleed air into the inlet of the Fan. This bleed air system was replaced with a two-inch recirculation pipe with a throttling valve between the fan discharge and inlet before the June 1996 stack test. This reduced the stack flow from about 200 cubic feet per minute to less than 30 cubic feet per minute.

Carbon Beds. The carbon operated well with very little pressure drop through the full scale remediation. The system ran dry until the Chiller Condenser failed. After that, water condensed in the carbon and was periodically drained off.

Vent Stack. The vent stack was initially a 6-inch diameter CPVC pipe. The top 15 feet of the vent was replaced with a 1.5-inch CPVC pipe before the June 1997 stack test. The gas flow was too low to be measured in the 6-inch pipe.

3.2.3 Wastewater Treatment Plant

The physical improvements to the water plant caused it to operate better during the full scale production than in the rapid start system, but the plant still experienced a number of difficulties. Based on experiences with the Guam water plant, a different type of water plant should be used. An alternative design is discussed in Section 6.0 of this report.

As shown on the flow sheets in Appendix A, all incoming wastewater entered the Surge Tank. The flows to the WWTP were not uniform in flow rate or composition. The Surge Tank provided a more uniform concentration and flow to the WWTP. Although liquid entered the Surge Tank at different rates, the tank could "surge" the liquid and pump out to the water plant at a constant rate. If the water level in the Surge Tank got low, the pump out rate could be reduced or turned off until the level came back up.

The Surge Tank was equipped with air spargers to provide agitation. These spargers were only partially effective, and 12 to 18 inches of mud built up in areas that were not agitated well. The Surge Tank used two synthetic liners to obtain secondary containment, and was under roof to exclude rain water and keep the sun off the liner. The clarifier set in the Surge Tank and the Surge Tank provided secondary containment for the clarifier. By the end of the job (about two years after the installation of the tank), the outer liner was starting to fail.

A submersible sump pump transferred the water from the Surge Tank to S-6020. As explained earlier, this tank was initially installed to separate out heavy oils, but no such oils were ever encountered.

Water gravity flowed from S-6020 to the Flocculation Tank, T-6030. As shown in the P&ID, a half section of pipe was welded onto the side of S-6020 and the wastewater flowed up this pipe to leave

the tank. A high speed agitator was installed in this pipe and the polymer was added to the water below the agitator. This section of pipe served as a rapid mix tank where the polymer was blended with the wastewater.

A variable speed floc agitator in the flocculation tank produced a much better floc than the high speed agitator in the rapid start system. Although settling was improved, the clarified water still contained a significant quantity of suspended solids. There still appeared to be organics in the water that created particles that did not settle well. From time to time, an oil sheen could be seen on parts of the surface of the water in the Surge Tank.

Wastewater gravity flowed from the Flocculation Tank to the Clarifier. The Clarifier was made from a fiberglass tank obtained on the island. The bottom of the tank was flat, and a perforated pipe running across the bottom of the tank was used to pump off sludge. This sludge removal system did not work well — sludge would build up in the clarifier and have to be cleaned out during maintenance shutdowns. A commercial clarifier has sloped sides that funnel the sludge to a central removal point. The clarifier feed contained 400 to 800 ppm suspended solids, and the effluent ranged 25 to 70 ppm suspended solids.

Water from the Clarifier gravity flowed to the Clarified Water Tank, T-6065. Water from Tank T-6065 could flow two ways, either to the WESP as recycle water, or to the oleophilic and carbon drums. The steam condensate continuously added water to the system and made the plant a net water generator, so there was always sufficient water to recycle to the WESP. As excess water accumulated and the liquid level in Tank T-6065 went up, the level indicator on the tank automatically opened a bypass valve to pump water through the rest of the water treatment plant.

Sludge was pumped from the bottom of the Clarifier to the Plate and Frame Filter Press to be dewatered. Filtrate was originally sent to the Clarified Water Tank, but because of the poor settling in the clarifier, the filtrate was cleaner than the clarified water. The system was repiped so the filtrate could be pumped through the rest of the water plant. At the end of the filtration cycle, the plates on the filter press were opened and the cake was dropped into a bin directly below the press. These solids were shoveled into 55-gallon drums for disposal as contaminated residuals.

Water from the Clarified Water Tank and filtrate going to further treatment first passed through one of two bag filters operating in parallel. Seventy micron bags were used, and some solids removal occurred in the bags.

From the bag filters, the water went through two 55-gallon oleophilic media drums operating in series. These drums contained a mixture of anthracite and clay, and are specifically designed to remove mechanically emulsified and free oils from water. This material is much more effective than carbon for removing free oils. Because the water still contained solids, the oleophilic drums acted as particulate filters and plugged after a couple of weeks in service. They were not removed because they saturated with oil, but because of excessive pressure drop caused by the fines buildup.

From the oleophilic drums, the water passed through two Carbon Tanks operating in series. From the Carbon Tanks, the water went to the Treated Water Supply Tank. From this tank it was pumped to the RKR product conveyor and used to cool the reactor product. Water usage on the product belt exceeded the amount generated by the water plant, and potable water was added to the Treated Water Tank as necessary to maintain water in the tank.

A bypass operated by two solenoid valves, HV 666 B and C, was available as a backup so the WESP could be supplied from the Treated Water Tank if the Clarified Water Tank were not available.

Water treated through the carbon was clear, but water recycled to the WESP turned light brown and developed an organic odor, the same as in the rapid start run.

Other than the Clarifier and Surge Tank, all the tanks in the WWTP set in the 30-by-40-foot building. The building provided secondary containment for the tanks.

3.2.4 Stack Test Results

NFESC stack tested the BCDP in June 1996.

3.2.4.1 BCDP Emissions Compared to Incinerator Emission Standards

The actual regulatory requirements for the BCDP are undefined. The EPA has different standards for different types of incinerators (i.e., municipal waste, medical waste, hazardous waste, etc.), and the BCDP is not an incinerator. The most stringent standards are for hazardous waste incinerators, and those standards will be used as a reference point for the BCDP emissions.

The BCDP stack is cleaner than required by the hazardous waste incinerator standards in every area except for carbon monoxide and hydrocarbon emissions. VOC emissions were 1.12 tons per year. These emissions are not a problem on Guam, but may be in some parts of the U.S. If control of these compounds is required, a small thermal oxidizer at the end of the APCS would destroy 99 percent to 99.9 percent of the hydrocarbons and carbon monoxide. The thermal oxidizer would not be burning PCBs. Almost all the PCBs are removed at this point in the system.

PCB Emissions. PCB DRE was 7 nines. This is better than the TSCA requirement of 6 nines for a hazardous waste incinerator. Stack flow during the PCB test averaged 23 dscfm.

Dioxin Furan Emissions. Dioxin and furan emission standards are set by the Resource Conservation and Recovery Act (RCRA). RCRA uses a TEQ measurement that relates the toxicity of all dioxin and furan isomers to that of the most toxic isomer: 2,3,7,8-TCDD (or tetra-chlorodibenzo-p-dioxin). The hazardous waste incinerator discharge limit is 0.2 nanograms per cubic meter. The BCDP tested at 0.18 nanograms per cubic meter with an average stack flow of 21 dscfm. Again, the BCDP emissions were cleaner than required by the hazardous waste incinerator standard.

Unlike the PCB DRE, which is based on mass flow, the TEQ is based on concentration. This is reasonable for comparing incinerators. Similar sized incinerators should have approximately the same off-gas flow rate. The BCDP's APCS, however, was designed to minimize off-gas flow — incinerators are direct-fired and have much higher stack flows. The flow correction below compares the BCDP's TEQ to the incinerator emission standard.

Data relating stack gas flow to production rate in tph were gathered on three IT incinerators and are summarized below:

Incinerator	Gas Flow (dscfm)	Tons Per Hour Feed Rate	dscfm/tph
Sikes	17,095	46.6	367
Bayou Bonfouca	15,127	28	540
Times Beach	19,150	41.8	459

Both Sikes and Bayou Bonfouca were burning hydrocarbon contaminated soil and Times Beach was processing PCB and dioxin contaminated soil. The average flow is 455 dscfm per tph of feed soil.

During the dioxin furan tests, the BCDP processing rate averaged 1.87 tph, and the stack flow averaged 21 dscfm. Compared to the BCDP, incinerators dilute pollutants. If the BCDP had the same dscfm off-gas flow as an incinerator, the flow at 1.87 tph would be:

$$1.87 * 455 = 853 \text{ dscfm}$$

At this flow, the TEQ concentration in the stack would be:

$$0.18 * (21/853) = 0.0044 \text{ nanograms per cubic meter}$$

This shows the BCDP to be $0.20/0.0044 = 45$ times lower in TEQ mass emissions than the incinerator standard.

Particulate Emissions. The particulate standard for incinerators is also a concentration limit, 0.030 grains per dry standard cubic foot (dscf). NFESC reported that the laboratory had problems with the particulate test, but the reported number was 3E-07 pounds per dscf, which is 0.002 grains per dscf. During the particulate test, the average production rate was 1.95 tph and the average flow was 24 dscfm. If these particulates had been in an incinerator, off-gas the concentration would be:

$$0.002 * (24/(1.95 * 455)) = 5.4E-05 \text{ grains per dscf}$$

This shows the BCDP to be $0.030/5.4E-05 = 555$ times below the incinerator particulate standard.

As stated earlier, the laboratory did not perform the test properly, but particulate emissions should be very low because the gas passes through a HEME, a three-inch thick tightly-woven filter media designed to remove submicron particles, before exiting the system. The HEME should stop virtually all particulate.

Metals Emissions. Metals were not sampled. Since the coral soil is naturally low in metals, there was no reason to believe that they existed. Depending on the metal, the new EPA limits for new (versus existing) incinerators range from 50 to 67 micrograms per dry standard cubic meter (0.022 to 0.029 grains per dscf). Because metals would be in the form of particulates in the off-gas passing through the HEME at about 50°F, metals emissions should be extremely low.

Hydrochloric Acid Emissions. The hydrochloric acid limit is 4 pounds per hour or 99 percent removal. The BCDP hydrochloric acid emissions were 1.5 milligrams per hour, over a million times below the limit.

Carbon Monoxide Emissions. The incinerator limit is 100 parts per million by volume (ppmv). The BCDP emissions were over 2,000 ppmv. The meter used to measure this value only reads to 2,000. The carbon monoxide emissions are 200 times above the incinerator limit. This could be corrected by installing a small thermal oxidizer at the end of the APCS, if required.

Hydrocarbon Emissions. The hazardous waste incinerator hydrocarbon limit is 12 ppmv. The BCDP was 160 times higher than this at 1,917 ppmv. Like carbon monoxide, this could be corrected by installing a small thermal oxidizer at the end of the APCS, if required.

3.3 Residuals

Because of the expense for disposal, the quantity of residuals that are generated by the BCDP is an important factor in the economics of the technology. The Demonstration Contractor processed about 50 tons of materials, starting with a clean system. Because unknown quantities of material remained in the ducting and equipment at the end of the demonstration run, the data could not be used to estimate the residuals generation rate expected during full scale remediation. Therefore, residuals are estimated based on the quantities generated after processing 5,550 tons of soil. These residuals include those generated in the rapid start run in 1995.

Table 3-5 shows the residuals inventory as of September 18, 1996. At that time, the BCDP had processed 5,550 tons of soil. Counting the weight of the 184 55-gallon steel drums, the residuals weight was 76,546 pounds, or 38.3 tons, 0.69 percent of the production to that point in time. Not including the weight of the drums in which the residuals were stored, 33.9 tons of residuals were produced for a residuals generation rate of 0.61 percent.

**Table 3-5
Residuals Inventory as of September 18, 1996**

	Number of Drums	Total Weight (pounds)	Weight Without Drums	Percent of Total
Multiclon Fines	59	22,740	19,909	29%
Granular Activated Carbon Drums	18	8,490	7,626	11%

Table 3-5
Residuals Inventory as of September 18, 1996

	Number of Drums	Total Weight (pounds)	Weight Without Drums	Percent of Total
Oleophilic Media Drums	15	5,058	4,338	6%
Spent Carbon	12	4,803	4,227	6%
Filter Press Cake	43	23,805	21,741	32%
Surge Tank Mud	4	2,420	2,228	3%
Air Carbon	3	1,344	1,200	2%
Personal Protective Equipment	18	3,469	2,605	4%
HEME Filters	5	911	671	1%
WESP/Decontamination Sludge	3	2,000	1,856	3%
Bag Filters	2	636	540	1%
Laboratory Waste	2	871	775	1%
TOTAL	184	76,546	67,714	100%

These residuals can be broadly grouped into three areas: air treatment residuals, water treatment chemicals, and miscellaneous.

The air treatment residuals include the air carbon, cyclone fines, filter cake from the water plant, Surge Tank mud, and WESP/decontamination sludge. While some of the filter cake from the water plant came from decontamination activities and storm water, most of it probably came from dust carried off the soil in the RKR and collected in the APCS. The Surge Tank "mud" was removed from the Surge Tank and drummed during a shutdown. The material was allowed to settle and decanted. Similarly, the WESP/decontamination sludge was removed from the WESP during a shutdown. These residuals from the APCS account for about 70 percent of all residuals.

The air carbon was changed once in October 1995, after the rapid start run, which processed about 650 tons of materials. Samples were taken at the inlet, midpoint, and exit of the 1,200 pounds of air carbon. The PCB concentration at those three points was 800 ppm, 12 ppm, and 1.2 ppm, respectively. Air carbon can hold several percent by weight PCB, so the carbon was probably far from being saturated and did not need to be changed at that point.

Water treatment chemicals, activated carbon, oleophilic media, and spent carbon accounted for 23 percent of the residuals. The Carbon Drums and Oleophilic Media Drums were pre-piped in 55-gallon drums used before the main carbon treatment tanks in the water plant. The spent carbon came from the carbon treatment vessels in the water plant. In every case, this material was replaced because of plugging with fines, not because of saturation and PCB breakthrough. Had the water plant been more effective at solids removal, the quantity of these residuals would have been lower.

The balance of the residuals, HEME filters, bag filters from the water plant, personal protective equipment, and laboratory waste accounted for about 7 percent of the total.

4.0 Economic Analysis

4.1 Actual Cost on Guam

Because the Guam BCDP was the first production BCDP ever built and operated, the direct result of a R&D effort, the actual costs experienced on Guam are higher than the cost would be if a new BCDP were built today. The cost analysis presented here does not include the R&D cost.

4.1.1 BCDP Capital Cost

The capital cost of the Guam BCDP unit is a combination of costs incurred by the Demonstration Contractor and the Remediation Contractor. Table 4-1 shows the purchase cost of equipment supplied by the Demonstration Contractor. Demonstration plant equipment that was not used in the full scale plant is crossed out and not included in the total demonstration plant equipment cost shown in Table 4-1.

Table 4-1 Purchase Cost of Equipment Supplied by the Demonstration Contractor That was Used in the Production Plant	
Equipment	June 1995 Cost
Rotary Kiln Reactor	\$407,000
Knife Gate Valves	\$2,500
Portable Crushing Plant	\$110,000
Pugmill	\$94,700
Feed Hopper/Conveyor Weighbelt	\$52,600
Bicarb feed Screw Conveyor	\$11,700
Reactor Outlet Conveyor	\$11,500
Portable Conveyor	\$2,890
Bin Vibrators	\$2,740
Platform Weigh Scales	\$8,700
Fuel Tanks	\$6,030
Baghouse	\$15,800
Cyclone	\$6,110
Wet Scrubbers	\$12,700
Forced Air Heat Exchanger	\$20,800
Induced Draft Fan	\$9,910
Compressor and Dryer	\$10,800

Table 4-1
**Purchase Cost of Equipment Supplied by the Demonstration Contractor That was Used
in the Production Plant**

Equipment	June 1995 Cost
Stainless and Carbon Steel Tanks	\$14,200
Agitators for Tanks	\$7,060
Butterfly Valve	\$3,300
Filter Press	\$15,500
Pumps	\$19,300
Air Carbon Tanks	\$16,100
Process Equipment Skids	\$14,800
Feed Shelter (20 by 30 feet)	\$2,500
Cost of Reused Demonstration Plant Equipment	\$707,000

The Pugmill was initially used to mix the soil and sodium bicarbonate. During remediation, the bicarbonate was added directly to the feed soil conveyor and mixed in the RKR. The redesigned APCS did not use any of the demonstration plant APCS equipment. The feed shelter was a steel frame structure covered with canvas that was purchased to keep excavated soil dry. This was used in the production system to cover the Surge Tank in the water treatment plant to exclude rain water. The forced air heat exchanger was initially used in the demonstration plant APCS. This exchanger was used in the production system to cool the WESP blowdown before it entered the WWTP. The demonstration air compressor and dryer was undersized for the new plant and in poor condition mechanically, largely as a result of having set outside in the Guam weather for several years. The air compressor was replaced by a new, larger unit.

Because of the research and development nature of this project combined with the overlapping of two contractors, it is very difficult to extract a realistic actual capital cost. Due to schedule pressures, the Remediation Contractor performed construction to convert the plant from a remediation plant to a production system while air pollution control equipment was being designed and purchased. Guam is a small island with a population of about 140,000. The typical construction trades that would normally be used, pipefitters, welders, etc., are not available on Guam. Most of the plant construction was done by the people who were sent over to operate the plant. Because of these factors, the construction costs were higher than they would have been had skilled trades people and

a complete design package been available when construction started. A more realistic capital cost can be derived by factoring total plant cost from the bare equipment cost.

Table 4-2 lists the new equipment that was purchased by the Remediation Contractor. Adding the demonstration Equipment Cost, \$707,000, to the new equipment cost, \$592,000, gives a total BCDP Bare Equipment Cost of \$1,299,000, say \$1,300,000.

Table 4-2 Purchase Cost of Equipment Purchased by the Remediation Contractor and Used in the Production Plant	
Equipment	June 1996 Cost
Cyclone	\$9,855
WESP	\$121,400
Primary Condenser	\$53,073
Chiller Condenser	\$125,750
Two HEME Tanks and Elements	\$17,500
Rotary Lobe ID Fan	\$11,835
Air Carbon Vessels and Carbon	\$3,750
Continuous Emissions Monitor	\$107,000
Boiler	\$57,300
Cooling Tower	\$5,756
Cooling Tower Pumps	\$8,838
WESP Recirculation Pump	\$6,710
Air Pollution Control System Subtotal	\$528,767
Flocculation Agitator	\$2,500
Clarifier	\$19,980
Water Carbon Units and Carbon	\$4,000
Water Plant Subtotal	\$26,480
Air Compressor and Dryer	\$14,725
Radial RKR Product Conveyor	\$21,745
Total New Equipment Cost	\$591,717
say	\$592,000

The ratios for cost elements shown in Table 4-3 are based on standard estimates for major additions to chemical processing operations at partially developed sites (Peters and Timmerhouse, 1991).

Table 4-3 provides ranges for the cost factors. The lower end of the range is used because much of the expensive equipment (the RKR, crusher, and feed conveyor) are mobile and delivered to the site in a condition that requires minimal set up. The estimated capital cost for the BCDP is \$3,692,000. A Feed Preparation Building for temporary storage was also constructed for about \$160,000, bringing the total cost to \$3,852,000.

Table 4-3 Factored Capital Cost Estimate for a BCDP Unit Constructed in the Continental U.S.			
Direct Costs	(Typical Ranges)	Factor Selected	Cost
Purchased Equipment	100%	100%	\$1,300,000
Installation	25 to 55%	30%	\$390,000
Instrumentation and Controls	6 to 30%	13%	\$169,000
Piping (installed)	16 to 66%	16%	\$208,000
Electrical (installed)	10 to 15%	10%	\$130,000
Site Preparation	10 to 20%	10%	\$130,000
Services/Support Facilities	30 to 80%	30%	\$390,000
Total Direct Cost	197 to 366%	209%	\$2,717,000
Indirect Costs			
Engineering - Percent of Total Direct Cost	16 to 30%	17%	\$221,000
Construction Expenses - Percent of Total Direct Cost	20 to 37%	21%	\$273,000
Total Indirect Cost	36 to 67%	38%	\$494,000
Contractor's Fee at 5 Percent Total Direct Cost and Total Indirect Cost	12 to 22%	12%	\$156,000
Contingency at 10 Percent Total Direct Cost and Total Indirect Cost	23 to 43%	25%	\$325,000
Fixed Capital Investment	268 to 498%	284%	\$3,692,000

4.1.2 Operating and Maintenance Cost on Guam

Table 4-4 shows the actual daily operating cost of the BCDP unit on Guam. These numbers came from the on-site cost tracking system. Diesel fuel and electricity were provided directly by the Navy. The electrical usage is for the process only, not the offices. Diesel fuel usage is for the plant as well as the heavy equipment used to excavate and handle the soil.

Table 4-4
BCDP Plant Daily Operating Cost on Guam

Cost Item	Daily Cost	Percent of Total
Site Labor	\$6,729	51%
Per Diem and Lodging	\$2,137	16%
Materials/Replacement Parts/Process Chemicals	\$584	4%
Excavation Equipment Rental	\$555	4%
Disposal of Residuals	\$540	4%
Guam Gross Receipts Tax	\$503	4%
Interim Trips Home	\$393	3%
Home Office Support	\$347	3%
Site Vehicles	\$289	2%
Diesel Fuel	\$365	3%
Shipping of Supplies and Equipment	\$209	2%
Cost Tracking and Accounting	\$152	1%
On-site Laboratory Supplies	\$147	1%
Electricity	\$194	1%
Office Supplies/Postage/Computers/Miscellaneous	\$109	1%
Health and Safety Supplies/Bottled Water	\$61	0.5%
Total Daily Operating Cost on Guam	\$13,313	

Monthly energy usage is shown in Table 4-5. Oddly, energy usage does not correspond well with production, so a daily cost will be used. Over the period shown in Table 4-5, the diesel fuel usage averages 365 gallons per day and electrical usage is 1,942 kilowatt-hour per day. Using a cost of \$1.00 per gallon for diesel and \$0.10 per kilowatt-hour for electrical, the daily cost is \$365 for diesel fuel and \$194 for electricity.

Table 4-5
Diesel Fuel and Electricity Usage Per Ton of Production

	Gallons Diesel Fuel	Kilowatt-hours Electrical Usage	Tons Production	Gallons Per Ton	Kilowatt-hour Per Ton
April	9645		719	13.4	0
May	13738		1032	13.3	
June	13461	46080	1085	12.4	42.47
July	12059	57300	729	16.5	78.60

Table 4-5
Diesel Fuel and Electricity Usage Per Ton of Production

	Gallons Diesel Fuel	Kilowatt-hours Electrical Usage	Tons Production	Gallons Per Ton	Kilowatt-hour Per Ton
August	10251	75480	742	13.8	101.73
September	7960	60400	564	14.1	107.09
Average				13.9	82.5

Over half the operating cost was labor. The plant was operated 24 hours a day, 7 days a week, by a staff of 20 people: 12 operators, 3 operations support people, and an office staff of 5.

Three 12-hour shifts each consisting of three operators and a shift supervisor (12 people total) ran the plant. Three additional people provided maintenance and did the excavation of contaminated soil and the backfill of treated product.

Plant support staff consisted of a Superintendent, Quality Control/Laboratory Manager, Engineer, Chemist, and Schedule/Cost/Procurement person. Except for Quality Control Samples, all the analytical tests necessary for the project were done in the on-site laboratory.

The second highest cost item, per diem and lodging, was 17 percent of the cost. Except for a local hire chemist, the plant staff all came from the mainland. Lodging was \$75 per day and per diem was \$50 per day. This was paid 7 days a week whether the person worked on a particular day or not. Because of this high cost of being on the island, the crew went to a standard 60-hour work week. The overtime was cheaper than the per diem. The weekly cost of $7(\$75 + \$50) = \$875$ is equivalent to an hourly wage of $\$875/40 = \21.88 per hour.

Out of the materials, replacement parts, and process chemical costs, about 40 percent were process chemicals. These consisted of sodium bicarbonate, carbon, polymer, and Oleophilic Media for the WWTP, and boiler and cooling tower water treatment chemicals.

The Navy provided a dump truck and front-end loader at no direct cost to the project. A trackhoe, rubber-tire loader, and breaker hammer (to break up coral) were rented on the mainland and shipped

to Guam. PCBs are a political issue on Guam, and the contractor was prohibited from renting equipment on the island that would be in contact with PCBs.

The BCDP generates contaminated residuals that amount to about 0.5 percent by weight of the soil treated. These are mainly dust captured by the cyclone in the APCS, dewatered sludge from the WWTP, contaminated Oleophilic Media from the water treatment plant, and contaminated carbon from the APCS and water plant.

Hazardous waste disposal is very expensive from Guam. The nearest hazardous waste disposal facility is over 6,000 miles away on the mainland. The waste must be shipped from Guam to the west coast, and then from the west coast port overland to the disposal facility. There is only one carrier who will transport waste from Guam to the mainland. They charge \$14,499 per 40-foot container. In addition, the waste must be placed in United Nations approved steel drums. Not being able to ship the waste in bulk is another significant cost increase. Residuals disposal from Guam is about \$2,100 per ton for landfill and \$3,100 per ton for incineration.

The Guam gross receipts tax, 4 percent of the daily cost, is a Government of Guam tax on the contract value of work done on Guam.

Every three months, each person at the site was provided with a round trip back to the mainland and two weeks home. The daily cost for the airfare was \$393, and this had another cost impact; when one of the 12 operators rotated home, the other operators worked extra hours to cover the vacancy. Since the operators were already scheduled for 60 hours per week, coverage for the off-island operator was 100 percent overtime. There are 13 weeks in a three-month period, and 12 operators gone two weeks every 13 weeks means that 24 weeks of coverage has to be provided every 13 weeks. The interim trips home significantly increased premium pay.

4.1.3 Per Ton Treatment Cost on Guam

The BCDP on Guam operated at 1.7 tph with an availability of 85 percent, for a daily average production rate of 34.7 tons. With a daily operating cost of \$13,313, the operating cost per ton is \$384. Based on the total tonnage for the project, 15,000 tons, and a capital cost of \$3,852,000, the pro-rated capital cost is \$257 per ton, for a total cost of \$641 per ton. This is high for mainland remediation, but remember that to send the soil off-island for landfill disposal would cost the same

as the residuals disposal, over \$2,000 per ton. Even if the equipment is not used again, the Navy's solution was much more cost effective than the alternative.

4.2 Cost of a New System in the Continental United States

Actual cost experience on Guam is used as the basis for estimating the cost of using the BCDP to remediate a mainland site.

4.2.1 Capital Cost

The RKR is the rate-limiting equipment at the Guam BCDP. The APCS was a "first-of-a-kind" unit and was designed conservatively. Based on actual versus design flows, the cyclone, WESP, and Primary Condenser operated at half design capacity when production was 2 tph. After the Primary Condenser, the off-gas flow rate dropped dramatically and the remaining equipment in the APCS was oversized by a factor of 16.

The RKR cost constitutes about 30 percent of the equipment cost. The kiln in Guam was designed for 1 tph, but was able to process at 2 tph for short times. The RKR would do 2 tph thermally, but not mechanically. At no significant change in cost, the Guam RKR could have been built as a 2 tph unit. The baseline for the RKR costs will be the Guam unit with a purchase cost of \$407,000 rated at 2 tph.

There are two ways to increase the RKR's capacity: make the unit larger and/or build the shell out of a material that can be operated at a higher temperature. The unit in Guam had a carbon steel shell, 30 feet long and 3 feet in diameter with a maximum temperature limit of 1,000°F. In June 1996, the RKR vendor quoted a price of \$60,000 for an alloy shell that could be operated at 1,400°F and \$25,000 for a replacement carbon steel shell. The RKR could thus be ordered with a shell that could be operated at 1,400°F for an additional \$35,000.

As a general rule, calciner capacity increases directly proportionally to increases in operating temperature. The alloy shell would thus allow the RKR to operate at a rate of:

$$2 * (1,400^{\circ}\text{F}/1,000^{\circ}\text{F}) = 2.8 \text{ tph}$$

Using a straight temperature ratio to calculate the rate increase in these temperature ranges is very conservative. Heat transfer between the shell and soil in the RKR is by conduction and radiation.

As the shell temperature increases through the 700°F to 1,000°F range, radiation becomes the dominant heat transfer mechanism. The conductive heat transfer rate increases directly proportionally to the temperature difference between the shell and soil, but the radiative heat transfer rate increases to the fourth power of the temperature difference. Above 1,000°F heat transfer will increase much faster than the ratio of the temperature difference.

Even assuming a linear increase of capacity with temperature, the alloy shell is very cost effective. The 2 tph RKR cost \$407,000, or \$203,500 per ton of capacity. The additional 0.8 tph for an additional \$35,000 is a cost of \$43,750 per ton of capacity.

As will be shown shortly, the most cost-effective size for a unit will depend on the size of the site (or sites, for a mobile unit) to which it will be applied. By their nature, indirect fired kilns like the RKR are limited to a smaller size than direct fired incinerators. Since the direct fired incinerator is heated from the end, the rotating shell can be supported at any point along the length of the shell. The indirect fired RKR, however, has burners located directly beneath the shell, and the shell can only be supported at each end. As the diameter or length of the shell is increased, the shell must be made of thicker material just to support its own weight. According to the RKR vendor, this limits the shell to about 9 feet in diameter.

If the larger RKR unit is to be mounted on a truck bed, the largest portable unit known by the authors has a 4.5 foot diameter shell that is 36 feet long. This unit will be used as a basis for developing the cost equations for a new BCDP. The capacity of a unit is controlled by the heat transfer rate and, in general, the heat transfer rate is proportional to the surface area of the shell. The existing RKR shell has a surface area of 212 square feet. The larger truck-mounted unit has an area of 573 square feet, for an increase in capacity to $(573/212) * 2.0 = 5.4$ tph. A regression analysis on calciner costs [7] shows that the ratio of shell areas raised to the 0.4 power is a reasonable predictor of costs. The cost of the 573 square foot unit is estimated to be:

$$\$407,000 * (573/212)^{0.4} = \$606,000$$

This larger unit with an alloy shell would have a capacity of:

$$5.4 \text{ tph} * (1,400^{\circ}\text{F}/1,000^{\circ}\text{F}) = 7.6 \text{ tph}$$

and an estimated cost of:

$$(\$407,000 + \$35,000) * (573/212)^{0.4} = \$658,000$$

This unit has 3.8 times the capacity of the Guam unit. Off-gas flows will increase in about the same proportion.

For cost scaling, the Guam BCDP can be divided into five sections:

1. The Cyclone, WESP, and Primary Condenser and their supporting equipment; the Cooling Tower; Cooling Tower Pumps; Boiler; and WESP Recirculation Pump were oversized in the Guam unit by a factor of 2 (i.e., these units would work on a 4 tph plant). Total bare equipment cost is \$262,932. This equipment cost will be estimated using the 0.6 rule.
2. The Chiller Condenser, HEME Tanks and Elements, ID Fan, and Air Carbon Units are oversized by a factor of 16 (i.e., these units would work on a 32 tph plant). Total bare equipment cost is \$158,835. This equipment cost will be estimated using the 0.6 rule.
3. The Continuous Emissions Monitor, an automatic stack sampling instrument, will have the same cost in any size plant. Total bare equipment cost is \$107,000, and the installed cost is estimated at \$214,000. This will be a constant for any plant size.
4. The Feed Preparation Building cost \$160,000. The cost of \$40 per square foot will be considered constant, and the cost will vary directly with the size of the plant.
5. The remaining bare equipment cost, \$364,233, will vary as the plant size varies and follow the 0.6 rule.

Using the installation factor of 2.84 to go from bare equipment cost to installed cost, the Capital Investment for the 7.6 tph unit is:

$$\begin{aligned} \text{Capital Investment} &= 2.84 * (\$658,000 * (7.6/7.6)^{0.4} + \$262,932 * (7.6/4)^{0.6} + \$158,835 * \\ &\quad (7.6/32)^{0.6} + \$364,233 * (7.6/2)^{0.6}) + \$214,000 + \$160,000 * (7.6/2) = \$6,283,000 \end{aligned}$$

The equipment cost of a BCDP with a different capacity can be estimated by substituting the tph of the new unit for the 7.6 tph in the above equation [the factor for kiln cost in the equation shown above, $(7.6/7.6)^{0.4}$, becomes $(\text{tph}/7.6)^{0.4}$].

4.2.2 Operating and Maintenance Cost

If this plant were on the mainland and the per diem and lodging, interim trips home, shipping of supplies and equipment (this charge is for packing and shipping connex boxes to Guam), and site vehicles were removed from the cost, the daily operating cost would drop to \$10,098 per day, lowering the per ton treatment cost to \$291.

A mainland plant would bulk ship the residuals instead of drumming them. Bulk incineration costs are about \$500 per ton, and overland shipping will be estimated at \$200 per ton. The costs on Guam were much higher because of the ocean shipping and the fact that the residuals had to be drummed. Residuals incineration cost on the mainland would drop to about \$700 per ton from \$3,100 per ton — a 73 percent reduction in cost. This lowers the operating cost to \$9,700 per day. The 4 percent Guam Gross Receipts Tax is left in the cost because there would likely be other local taxes at a different location. Unlike most locations in the United States, Guam has no sales tax.

Operating costs in the continental U.S. are estimated using the information in Table 4-6. Table 4-6 shows the daily cost in Guam, and then breaks the cost down into two categories, "mainland fixed" and "mainland variable."

Table 4-6 BCDP Daily Operating Cost on Guam and Fixed and Variable Operating Cost for a Mainland BCDP			
	Guam	Mainland Fixed	Mainland Variable
Site Labor	\$6,729	\$6,729	
Per Diem and Lodging	\$2,137		
Materials/Parts/Process Chemicals	\$584		\$584
Excavation Equipment Rental	\$555	\$555	
Disposal of Residuals	\$540		\$146
Guam Gross Receipts Tax	\$503		\$503
Interim Trips Home	\$393		
Home Office Support	\$347	\$347	
Site Vehicles	\$289		

	Guam	Mainland Fixed	Mainland Variable
Diesel Fuel	\$365		\$365
Shipping Supplies and Equipment	\$209		
Cost Tracking and Accounting	\$152	\$152	
On-site Laboratory Supplies	\$147	\$147	
Electricity	\$194		\$194
Office Supplies/Postage/Computers/Miscellaneous	\$109	\$109	
Health and Safety Supplies	\$61	\$61	
TOTAL COST	\$13,313	\$8,098	\$1,792

The mainland fixed costs are daily costs that will not change significantly as plant size changes, i.e., they tend to be fixed daily costs for the sizes of plants we are considering. The variable costs, such as fuel and residuals disposal costs, will increase as plant size increases. Table 4-6 also shows Guam costs that are not applicable to a mainland plant.

The operating model has a fixed cost of \$8,098 per day and a variable cost of \$1,792 per day that is assumed to vary directly with plant capacity. These costs are for a 2 tph plant. The daily operating costs for a 7.6 tph plant are:

$$\text{Operating Cost} = \$8,098 + \$1,792 * (7.6/2) = \$14,908$$

and the daily per ton operating cost is $\$14,908/155 = \96 per ton. The operating cost for a different size unit can be estimated by substituting the unit's capacity in tph for the 7.6 in the equation above.

4.2.3 Cost as a Function of Site Size

The optimum size (i.e., minimum cost) plant for a given site must take into account both capital and operating cost. To build a cost model over the range of 0.5 to 10 tph, the following assumptions are made:

1. The BCDP will be used for one site and then scrapped. No scrap value is allowed — the scrap value covers the cost to demobilize the plant.

2. The cost equations for capital and operating costs developed in the previous section are valid over the 0.5 to 10 tph range.

Remember that the costs developed are for a complete, fully staffed plant. The labor required to operate the 2 tph plant in Guam would be sufficient to operate a 10 tph plant. On the smaller end of the scale, below 1 tph, labor reductions could be made, but the type of plant would have to change significantly from the BCDP Guam operation to take advantage of the smaller size.

Table 4-7 shows the cost for building and operating different size BCDPs to remediate a 10,000 ton site. The tons per day capacity is calculated from the tph rating assuming an 85 percent availability. The per ton operating cost is calculated by dividing the daily operating cost by the tons per day production. The total cost is the capital cost plus the per ton operating cost times the number of tons at the site. The per ton cost is the total cost divided by the number of tons processed.

Table 4-7 Capital, Operating, and Total Cost for Different Capacity BCDP Units Built and Operated to Treat 10,000 Tons of Soil at One Site						
Tons Per Hour	Tons Per Day	Capital Cost	Daily Operating Cost	Operating Cost Per Ton	Total Cost	Per Ton Cost
0.5	10.2	\$1,585,127	\$8,546	\$838	\$9,963,558	\$996
1	20.4	\$2,188,151	\$8,994	\$441	\$6,596,974	\$660
2	40.8	\$3,082,090	\$9,890	\$242	\$5,506,110	\$551
3	61.2	\$3,799,127	\$10,786	\$176	\$5,561,545	\$556
4	81.6	\$4,423,741	\$11,682	\$143	\$5,855,359	\$586
5	102	\$4,988,860	\$12,578	\$123	\$6,221,998	\$622
6	122.4	\$5,511,459	\$13,474	\$110	\$6,612,276	\$661
7	142.8	\$6,001,667	\$14,370	\$101	\$7,007,969	\$701
8	163.2	\$6,466,109	\$15,266	\$94	\$7,401,526	\$740
9	183.6	\$6,909,406	\$16,162	\$88	\$7,789,690	\$779
10	204	\$7,334,932	\$17,058	\$84	\$8,171,108	\$817

This analysis was done for sites ranging from 5,000 to 100,000 tons. The results are shown in Figure 4-1. Several conclusions can be made.

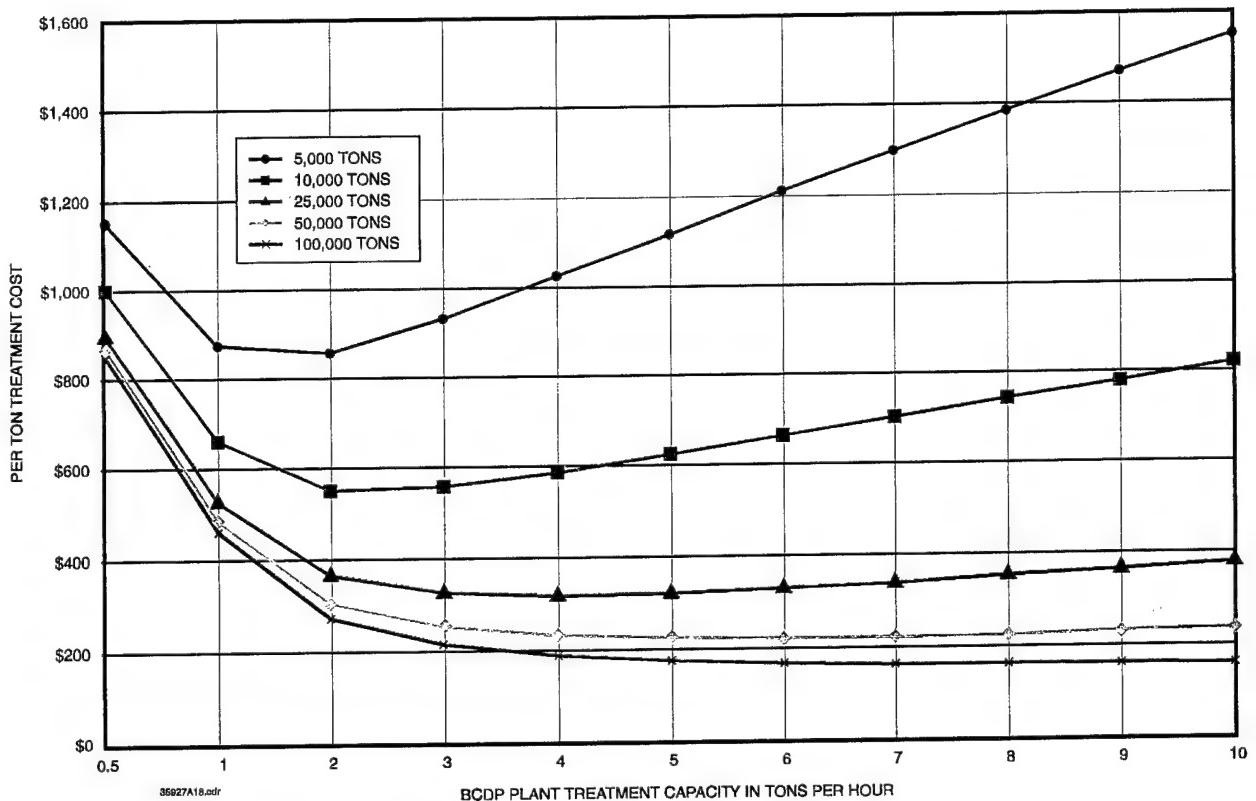


Figure 4-1
Per Ton Treatment Cost for a Given Site Size for a BCDP Built and Used for One Site Only

There is a minimum cost plant size for a given site size. Plants smaller than the minimum cost plant for a given site size are more expensive because of high operating cost. If the plant is too large for the site, the capital cost is not spread out over enough tons of material to be economical.

For sites larger than about 25,000 tons and plants over about 3 tph the costs flatten and are not very sensitive to changes in plant size or site size. The BCDP is very competitive with commercial incinerator costs for sites above 25,000 tons. For sites smaller than about 7,500 tons, hauling the material to a commercial incinerator would be cheaper than building this type of unit to remediate the site. Between these upper and lower site sizes, a site-specific study would need to be made to develop the best alternative. Remember that this analysis is for building a unit for use at a single site. A unit that can be moved and reused would make smaller sites more practical, and multiple, larger sites even more economical.

It is unlikely that the equipment would be scrapped after one job. Even the 7.6 tph RKR can be mounted on a truck and moved from site to site. If the unit is moved and used on multiple sites, the model here would have to be modified by the addition of mobilization and demobilization costs.

To better define the optimum plant size for a given site size, the derivative of the total site cost equation was taken relative to tph and set equal to zero, then solved for site size. Based on our model, the minimum cost plant size (tph) for a given site size in tons (S) is:

$$S = 837 * \text{tph}^{1.4} + 1608 * \text{tph}^{1.6} + 202 * \text{tph}^2$$

This equation is plotted in Figure 4-2. Figure 4-2 plots per ton cost against the minimum cost plant size and site size. Of these two variables, site size is by far the more important above a processing rate of 2 tph. Although the minimum cost plant for a 50,000 ton site is about 6.5 tph, as shown in Figure 4-2, the per ton treatment cost, as shown in Figure 4-1, varies only slightly for plant sizes between 5 and 10 tph.

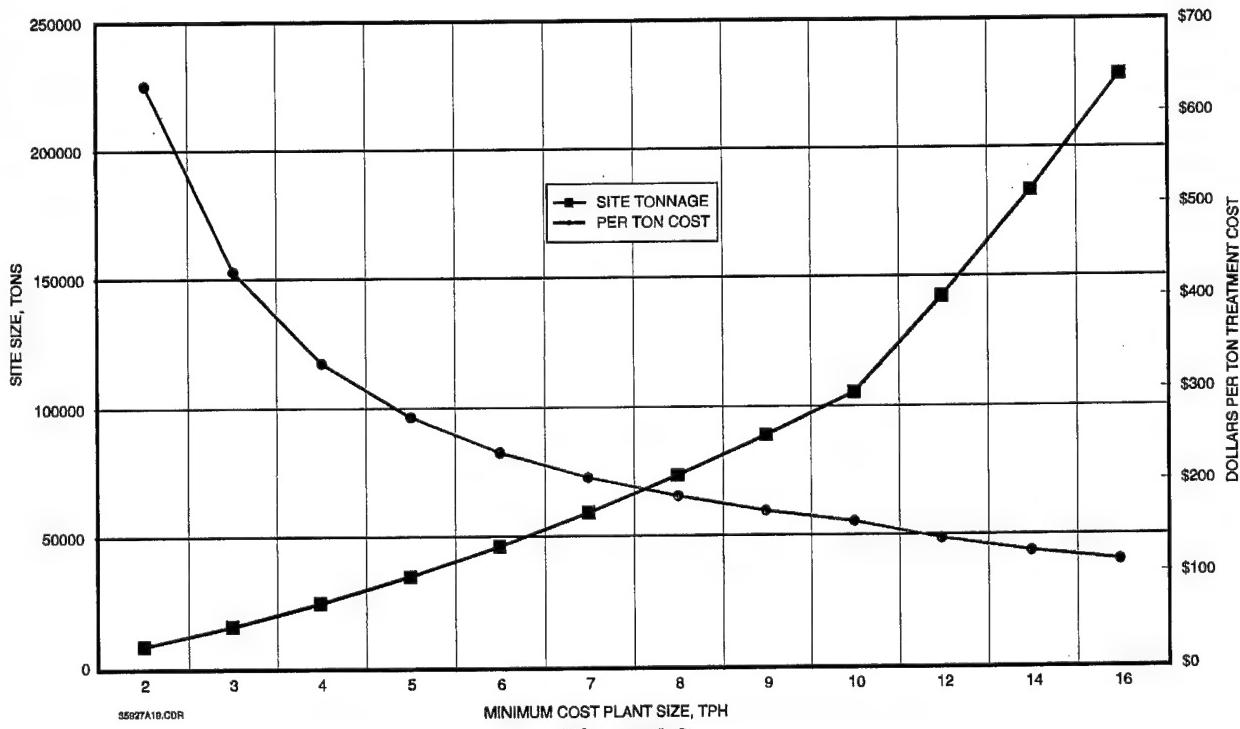


Figure 4-2
Minimum Cost Plant Size for a Given Site Size and
The Corresponding Dollar Per Ton Treatment Cost

Table 4-8 shows the optimum range of plant sizes for various site sizes and the corresponding treatment cost and job duration (excluding mobilization and demobilization time). Again the insensitivity of plant size to cost is apparent, especially as the site becomes larger. For a very large plant, the cost drops below \$100 per ton. For large sites, the BCDP is competitive with landfilling.

Table 4-8 The Optimum Range of BCDP Plant Size to Treat Large Sites and The Corresponding Cost Per Ton and Treatment Duration					
Site Size (tons)	Dollars Per Ton	Minimum Tons Per Hour	Maximum Tons Per Hour	Maximum Days	Minimum Days
25,000	\$320	4	4	306	306
50,000	\$220	6	6	408	408
100,000	\$157	8	12	613	408
150,000	\$134	11	18	668	408
200,000	\$117	12	19	817	516
250,000	\$107	14	22	875	557
300,000	\$100	15	25	980	588
500,000	\$85	19	36	1,290	681

The price for incinerators remediating large sites is in the \$200 to \$250 per ton range. Many Superfund incineration sites that are bid on a unit price basis involve other operations, such as sludge dewatering, bioremediation, etc., making it difficult to extract the cost charged for incineration alone. One Superfund site that was remediated by incineration alone was Sikes, located north of Houston, Texas. The original bid was to incinerate 341,000 tons for \$90,000,000 (\$264 per ton). Before the job ended, an additional 163,000 tons was remediated for an additional \$30,000,000 (\$184 per ton). This job was completed in 1995.

For large plants, above 10 or 15 tph, the configuration of the plant would probably change. Because of the size limits on the RKR, at some point two RKRs might have to be installed to achieve the desired capacity. Especially for the large sites with a broad range of optimum plant size, the smallest "optimum size" plant would probably be favored economically. This analysis has not included the cost of money, but that would have to be considered in the analysis of a specific site. A 200,000 ton site, for example, could be completed in 516 days with a 19 tph BCDP, or in 817 days with a 12 tph BCDP. The larger unit would require a greater cash outlay at the beginning of the job, but the payment for the job would also be collected quicker.

5.0 Technology Applicability

BCDP can be used to treat the same type of material that can be treated by a thermal desorber; contaminated soils, sludges, and filter cakes. If PCBs (and possibly other chlorinated compounds) are treated, the bicarbonate catalyst will increase plant efficiency by allowing the soil to be cleaned at a lower temperature and chemically destroying some of the PCBs.

Although the BCDP was initially designed to treat PCB-contaminated soil, its performance on other types of contaminants can be predicted. The BCDP will remove both volatile and semivolatile compounds from soil, including very low volatility chlorinated organics. The performance of the APCS depends largely on the nature of the organics to be removed. High boiling point organics, such as PCBs, are largely removed by condensation and captured on either the WESP or the HEME. Semivolatile water soluble organics are captured in the WESP water by solubilizing into that water. Volatile non-water soluble organics and residual PCB vapors are captured by carbon absorption at the end of the APCS.

Laboratory studies have shown the benefits of bicarbonate when treating PCB contaminated soil. The bicarbonate's effectiveness on other types of contaminated soil is unknown, but the APCS should be just as effective if the unit were operated as a thermal desorber on any soil contaminated with organic compounds having vapor pressures similar to PCBs.

Compounds such as PCBs, which may react with oxygen at elevated temperatures to form even more hazardous compounds such as dioxins, are especially suited to the BCDP. The inert steam atmosphere in the RKR and throughout the APCS excludes most of the oxygen. The sodium bicarbonate breaks down, releasing carbon dioxide and water to add additional inert gases to the system. At high temperatures, in the absence of oxygen, some pyrolysis will occur and actually break down larger molecules into smaller and, in many cases, less toxic compounds.

The primary factors affecting contaminant removal in the RKR are temperature and residence time. As an example, PCB-contaminated soil requires a temperature of approximately 600°F at a residence time of about one-half hour. As the temperature is raised, the residence time can be reduced. These numbers are approximate because the type of soil that the PCBs are in is also a factor. The total quantity of organics that is released in the RKR is an important factor in the overall economics of the system. Since only partial destruction of PCBs is caused by the bicarbonate, all the condensable

organics that are released will likely be contaminated with PCBs. This contaminated residual can be disposed of off site, typically by incineration.

Table 5-1 lists the codes for some specific RCRA wastes that can be treated by this technology. These compounds can all be successfully treated in standard thermal desorbers, therefore, they should be treatable with the BCDP. General contaminant groups that can be treated by the BCDP are shown in Table 5-2. This table is based on current available information for treatment by thermal desorption.

**Table 5-1
RCRA Codes for Wastes Treatable by BCDP**

Type	Code
Wood Treating Wastes	K001
Dissolved Air Flotation Float	K048
Slop Oil Emulsion Solids	K049
Heat Exchanger Bundles Cleaning Sludge	K050
API Separator Sludge	K051
Tank Bottoms (Leaded)	K052

**Table 5-2
General Contaminant Groups Treatable by BCDP**

Nonhalogenated and Halogenated
Volatiles and Semivolatiles
PCBs
Pesticides
Dioxins/Furans
Organic Cyanides
Volatile Metals

Individual site conditions must be considered to determine the effectiveness of the BCDP. For example, PCBs are released fairly quickly from the coral matrix found in Guam. It is expected that PCBs would be more tightly bound to clay, and that higher temperatures or longer residence times would be required if the PCBs were on clay instead of coral. If the PCBs at a particular site were found together with high levels of nonhazardous organics, the quantity of residuals that would be generated for off-site disposal would be increased.

6.0 Conclusions and Recommendations

6.1 Conclusions

The operation of the BCDP for over a year on Guam to successfully remediate 11,700 tons of PCB contaminated soil has proven the effectiveness of the system for PCB remediation.

The equipment is relatively easy to operate and very protective of the environment. The system has zero water discharge and the air emissions are better than required by the hazardous waste incinerator standards. The APCS is not subject to the upsets that can occur in incinerators. Since the RKR and APCS are operated under an inert atmosphere, there is no danger of igniting the organics that are driven off the soil and creating a positive pressure in the system that could result in uncontrolled emissions. A positive pressure was never recorded in the APCS during the remediation on Guam.

Sodium bicarbonate addition was reduced to levels well below the 10 percent initially recommended and the unit was also successfully operated without bicarbonate addition. This confirms the results of similar testing reported by the Demonstration Contractor ([6], p. 7.2). It is well established that thermal desorption without bicarbonate will remove PCBs from soil [13], [14], but laboratory studies have shown that the bicarbonate causes the PCBs to be released faster and at a lower temperature -- which would mean that RKR capacity can be increased by adding bicarbonate. The use of bicarbonate is an economic issue, a trade-off between the cost of adding bicarbonate and the cost savings that would be incurred by increased RKR capacity. No data were collected that would help define this trade-off.

6.2 Recommendations

The previous sections of this report have discussed the BCDP Guam plant and described how it was built and operated. Based on what was learned on Guam, a number of design improvements can be made for the next BCDP unit. These recommended design changes are discussed in this section.

The recommendations have not been tried, and there is no guarantee of their effectiveness.

6.2.1 Feed Handling and Preparation

A larger Feed Preparation Building would have been cost-effective on Guam because the operating rate was limited by a shortage of dry feed during the rainy season. The feed can only be crushed when it is dry, and Guam gets 15 to 20 inches of rain a month during the rainy season. For weeks

at a time during the rainy season the soil was too wet to crush. The quantity of dry feed inventory and thus, the size of the Feed Preparation Building must be determined on a site-specific basis on rainfall data and the type of soil being processed.

A screening plant after the crusher would have been useful to remove roots, debris, and larger rocks that passed through the crusher. This material would sometimes jam the dual knife gate feed system on the RKR. Recycling and crushing the larger rocks would produce a more uniform particle size feed that would allow higher capacities if the operation is thermally limited. The screening plant would also provide some redundancy for the crusher. In case the crusher broke down, feed material (i.e., material passed through the screen) could still be produced by screening out and stockpiling oversized material until the crusher was repaired.

6.2.2 Rotary Kiln Reactor

The RKR should have an alloy shell capable of handling a higher temperature than the carbon steel shell on Guam. This is a cost-effective way to increase the RKR's capacity.

According to discussions with the vendor, part of the reason that soil feed fell into the RKR breach is that the RKR was designed to operate at one tph of soil. There are flights at the soil entrance side of the shell that move the soil away from the feed pipe and into the shell. These flights on the Guam BCDP were designed for one tph, and had difficulty handling rates above 1.5 tph. It is difficult to predict, in advance, the actual processing rate that can be achieved by a given RKR at a given site. The unit will normally be limited thermally, and should be designed so that feed soil will be carried away from the breech at any rate at which the unit might be operated.

Part of the reason why only 4 of the 14 burners would maintain the design temperatures when feeding 1.5 tph of soil is that the design specification gave the soil moisture at 26 percent. Actual soil moisture was around 10 percent. Temperature control would have been more uniform across the shell if more burners could have been operated. Careful attention should be paid to burner sizing.

6.2.3 Reactor Product Handling System

Particulate emissions were a problem, and depending on the wind conditions, we exceeded the ambient standards at the site boundary, which was only about 30 feet from the product bins. One solution is to dump the hot product directly from the kiln into a jacketed mixer. Water is sprayed on the soil in the mixer. The water evaporates and then recondenses on the walls of the mixer. Heat

is removed by the cooling water on the jacket. The amount of water sprayed can be adjusted to provide a moist product that does not dust as it discharges from the mixer to the product conveyor belt. The discharge from the mixer must be from dual knife gate valves or another system that provides a seal.

Another solution sometimes used on indirect-fired kilns is to have a water spray cooling section at the end of the kiln that is attached to, and rotates with, the heated portion of the kiln ([7], p. 20-41). In this application, the clean fines released when the water sprays on the hot product will be swept out the feed end of the kiln with the contaminated fines and increase the quantity of contaminated residuals. There would be some energy savings because sweep steam would be generated from the heat in the product. Calculations would have to be done to insure that the amount of steam generated was low enough not to exceed the minimum sweep gas velocity. Excess sweep gas flow will increase the quantity of contaminated fines collected in the APCS.

6.2.4 Air Pollution Control System

This section discusses potential improvements that could be made if a project similar to the Guam project were repeated. Like other parts of the BCDP, if the process is to be used at a different location, with a different contaminant, and different air pollution regulations, an engineering study should be done to insure that an optimal system has been designed.

Significant improvements can be made in almost every part of the APCS that will lower cost and improve efficiency. Each element of the system is discussed individually.

Multicloner. The Multicloner was oversized for the actual gas flow encountered, and as a result did not operate efficiently. Although operating efficiency would have been greatly improved if two of the three clones were plugged, it was physically difficult to do this. The Multicloner on the next unit can be designed much more accurately because actual operating conditions are now known. To increase flexibility, the unit should be built so that the cones can be easily accessed for plugging.

WESP. Most of the operating problems in the APCS were with the WESP, and these problems were caused by two things: the buildup of solids in the WESP sump and recycle streams and pumping problems caused by the high temperature of the water in the WESP sump. Design changes in the next BCDP should eliminate both problems.

The solids plugged and eroded the spray nozzles, and required that the WESP be shut down from time to time and flushed. Solids buildup in the WESP caused the operating voltage to drop and thus reduce the removal efficiency of the WESP. While this probably did not have an impact on air emissions, it did allow contaminated gas to reach and foul the insulators at the top of the WESP.

Raising the blowdown to between 10 and 15 gpm helped keep the WESP cleaner. The increased blowdown required a corresponding increased addition of cool make-up water and steam injection to maintain temperature. A heat exchanger should be installed to exchange heat between the blowdown and make-up water. The blowdown needs to be cooled before it enters the water treatment plant, and preheating the make-up water will reduce steam consumption. The water treatment plant will have to be designed to handle the increased blowdown.

The WESP pump has a difficult job because of the high water temperature it is pumping. The progressing cavity pump worked better than the diaphragm pumps, but some cavitation that caused vibrations in the discharge piping occurred. Careful attention must be paid to the NPSH requirements. The pump suction line from the WESP should be designed to have minimal pressure drop, and it may be necessary to increase the sump depth or mount the WESP higher off the ground to raise the liquid level in the sump. Operating the WESP at as low a temperature as possible (above 198°F) will increase the NPSH significantly.

Figure 6-1 shows a design that would solve the problems mentioned above. The WESP blowdown is 100 percent and all the water feeding the WESP spray nozzles has been through the WWTP, thus it will be very low in solids. The blowdown passed through a heat exchanger where it is cooled by the make-up water (the Guam unit used an air heat exchanger to cool the blowdown because one was available on site). A side stream is taken off the cooled blowdown and sent to the suction side of the WESP blowdown pump. This water is injected to cool the pump suction liquid enough to avoid NPSH problems. The amount of cooling water injected is determined by a temperature controller in the WESP blowdown pump discharge. It may be necessary to add some supplemental steam to the water going to the WESP to insure that the temperature is close to the WESP operating temperature.

Much of the solids problem was caused by the poor operation of the cyclone, discussed earlier. Improving cyclone operation will significantly reduce the amount of solids sent to the WESP.

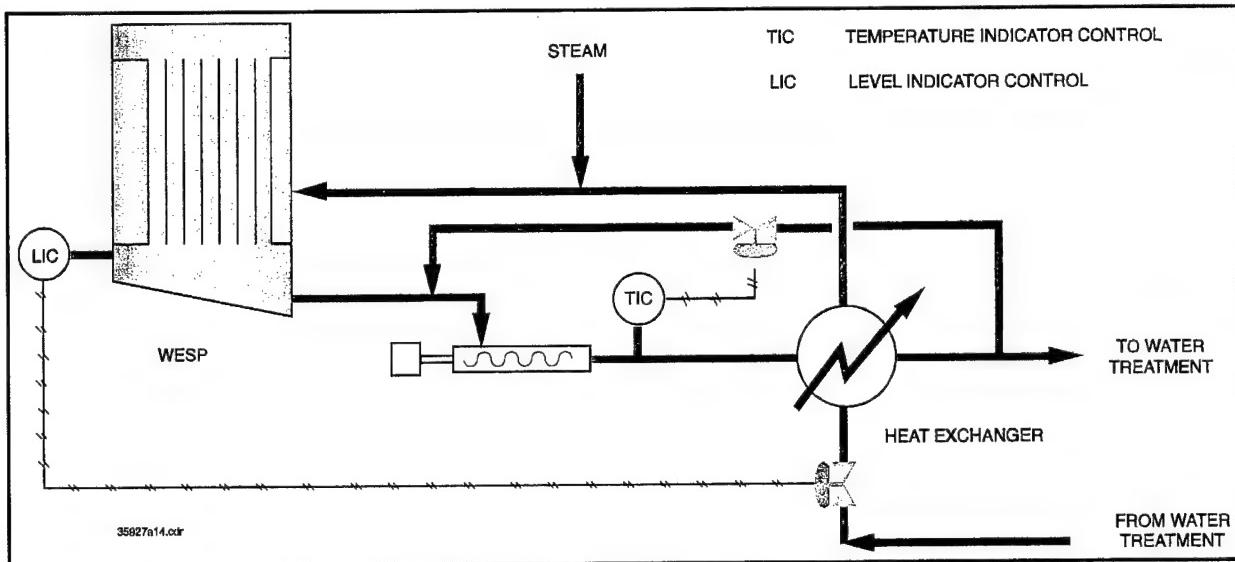


Figure 6-1
Alternative WESP Water Usage Design

The piping between the WESP pump discharge and the WESP should be insulated to conserve heat.

The make-up water to the WESP should be added continuously through a control valve instead of through an on/off solenoid valve. Adding the cold water intermittently created temperature swings in the WESP that a continuous addition would eliminate. The intermittent addition also required the level in the WESP to oscillate, which changes the NPSH available on the WESP pump. Maintaining a constant level would allow the NPSH available to be kept at a maximum, and Figure 6-1 incorporates that design.

The spray nozzle header pipes in the WESP should be designed so they can be easily removed for cleaning and replacing the nozzles.

Standard WESP design practice locates the insulators on top of the WESP, directly over the top wire support grid. Each of the four insulators is housed in a compartment and preheated air is blown into the insulator compartments. This air exits into the main body of the WESP. The continuous flow of clean, hot air across the insulators and into the WESP prevents condensation from forming on the insulators and prevents dirty gases in the WESP (dirty gases would be present in the top of the WESP when an upset condition occurs) from condensing and depositing material on the insulators. Condensation on the insulators will cause an electrical short circuit that will drop the voltage in the WESP.

The Guam WESP design put the insulators on the side of the WESP to remove them from the main gas flow (Figure 3-2). This was not sufficient and the insulators became dirty and had to be cleaned periodically. A teflon sheet should be added to reduce the opening between the insulator compartment and the body of the WESP, similar to the teflon sheet that was added between the bus duct and the insulator compartment (Figure 3-2). Two 6-inch diameter holes would be cut in each of the two sheets for the upper wire support bars. This would provide the same clearance between the support bars and teflon that exists between the wires and tubes in the WESP. If the teflon becomes dirty, it can become conductive. The 6-inch holes should provide enough clearance to prevent a short from occurring between the support bars and dirty teflon. Drain holes should be provided in the bottom of the teflon sheet in case condensation occurred in the insulator compartment when the WESP is down or when the deluge wash system is used. As mentioned earlier, eliminating the solids buildup in the WESP will allow the unit to operate much more efficiently, and keep the gas in the upper part of the WESP clean.

The WESP outlet temperature thermocouple would sometime foul and read low. This automatically increased the amount of WESP injection steam. Since this thermocouple reading is very important for safety reasons, a redundant thermocouple could be installed in the WESP outlet duct closer to the Primary Condenser inlet. Comparing these two readings would provide a warning if one of the thermocouples started to fail or foul.

Primary Condenser. This unit operated with very few problems. The tubes required cleaning every few months and the design and installation should make access to the top tube sheet as easy as practical.

The condensate pumps were air-operated diaphragm pumps because there was a concern that insoluble organics would drop out at this point and an emulsion could be formed with a high shear pump. The condensate was always very clear, and there was never any sign of a risk of forming an emulsion. Low head centrifugal pumps would probably be more reliable, and would certainly be quieter.

Venturi Scrubber. This equipment is not needed.

Chiller Condenser. This unit served two purposes, to condense additional PCBs and make them available for removal in the HEMEs and to dry the gas stream. The requirement for this unit should be examined on a site-specific basis.

On Guam, the ambient temperature does not drop below about 65°F, so cooling the gas to between 40°F and 50°F insures a dry gas. This will not work in a location with an ambient temperature below freezing. Heaters would have to be added to insure that the gas heats up after leaving the chiller. The dry gas prevents condensation in the rest of the system and increases the holding capacity of the carbon (by keeping the carbon dry).

The Chiller Condenser on Guam was designed for a gas stream of 377 acfm at 120°F. The actual conditions were a gas stream of 30 acfm at 80°F. Most other locations would have colder Cooling Tower water and a correspondingly lower Primary Condenser outlet gas temperature. This would reduce the size of the Chiller Condenser unit even more. The Chiller Condenser will be much smaller (and lower in cost) on the next unit.

HEMEs. The two HEMEs were piped in parallel. They should be piped in series, like the carbon, so that flow can be directed through a single HEME if the other element has to be changed. The cost for additional pipe and valves will be minimal because the gas flow is low at this point and the piping is CPVC.

Having the two HEMEs in series will provide even better gas cleaning efficiency, at almost no increase in cost. During the months of operation of the full scale system, the pressure drop across the HEME in use remained below 0.5 inches of water. The second HEME should stay very clean (relative to the first HEME), thus the pressure drop across the second HEME should always be much lower than the first HEME.

The HEMEs are designed to remove condensed liquids, not vapors. As the unit operates and loads up with lighter organics (organics that pass through the WESP), those organics could remove PCB vapors by solubilization. This removal mechanism was discussed in Section 2.3.1 for water soluble organics in water in the WESP and primary condenser. PCBs are not water soluble, but they are soluble in other organics. It might be that if the HEME were wetted with an organic before being placed into service, it would remove significant quantities of PCB vapor.

Like the rest of the equipment after the Primary Condenser, the HEMEs in Guam were oversized. These units are relatively cheap, and making them larger than recommended by the vendor has some advantages. There air cleaning efficiency and their capacity for holding organics and maintaining a low pressure drop increases as they become larger. The HEMEs in the Guam BCDP were designed for a flow of 400 acfm, but were operated at about 30 acfm in the full scale system.

ID Fan. A much smaller unit should be installed and the recirculation line between the suction and discharge of the ID Fan eliminated. The silencers are probably not needed for the required flow and pressure drop, but the vendor should be consulted about noise levels with and without the silencers at the design flow conditions.

The ID Fan is the only mechanical component of the APCS whose failure can cause uncontrolled emissions. A spare ID Fan should be installed in parallel. Because these fans are very small and the piping is CPVC, the cost of a spare fan will be minimal.

Air Carbon Units. The air carbon units were designed for a gas flow of 550 acfm, versus the actual flow of about 30 acfm. Like the HEME, this is inexpensive protection, and maintaining a similar ratio of carbon-to-gas flow will not significantly increase capital or operating cost.

APCS Gas Piping. The piping can change from carbon steel to CPVC at the exit of the Primary Condenser. The WESP and Primary Condenser bypass piping can be eliminated. All the gas piping in the Guam BCDP was much larger than necessary. The gas piping after the Primary Condenser could all be changed to 2 inches. Gas flows on the PFDs should be referenced to determine the proper pipe size.

Preventing air leaks in the APCS is very important, and all the piping and equipment should be installed as air-tight as possible. From the RKR to the ID Fan, the APCS operates under a vacuum, and any leak will draw air (and oxygen) into the system.

Thermal Oxidizer. If the BCDP is operated in an area with strict VOC emission standards, a thermal oxidizer after the carbon could be used to destroy the VOCs. A thermal oxidizer should also reduce the odor that comes from the plant. Because of the low stack gas flow, the unit would not be very expensive.

Boiler. The boiler was designed for 2,760 pounds per hour of steam. Actual usage never exceed 1,000 pounds per hour, and usually ran around 600 pounds per hour. A 1,000 pound per hour boiler would be sufficient for this size plant.

6.2.5 Wastewater Treatment Plant

Much of the WWTP was constructed from equipment left over from the demonstration plant and surplus equipment. Tank capacities, pump sizes, and other parameters in the Guam BCDP plant are generally not at their optimum size, but they functioned acceptably.

Proposed WWTP Design. The solids removal portion of the Guam WWTP was a standard flocculation and clarification system. The wastewater, however, contained insoluble organics that were not readily removed from the water by this type of plant. A more efficient design for a plant to treat the BCDP wastewater is shown in Figure 6-2.

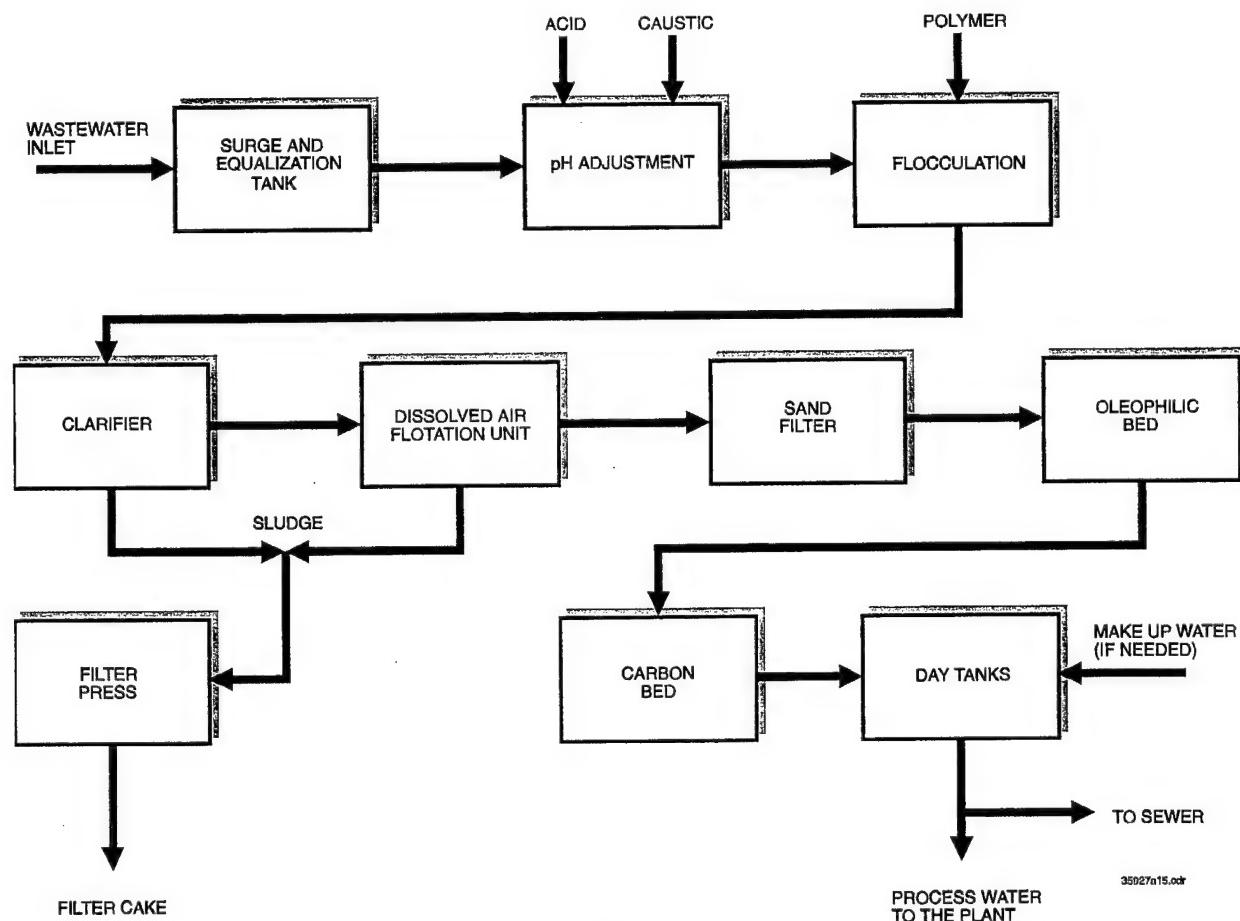


Figure 6-2
Proposed WWTP for the BCDP

The proposed plant uses settling followed by dissolved air flotation to remove solids. This is the same solids removal system used in petroleum refinery WWTPs which treat a wastewater that is similar to the BCDP wastewater. The water contains solids, dissolved organics, and non-water soluble organics.

Normally, dust from soil has a higher density than water and will sink. This type of material is easily removed in a clarifier. Some of the insoluble oils in the water, however, are lighter than water. When these light oils and the dust particles are mixed, some of the particles will be “wetted” with the oil. The insoluble oil is hydrophobic, and will preferentially partition from the water to the solids. When the heavier than water solids mix with the lighter than water oil, the resulting particle can float, sink, or stay suspended, depending on the composition of the particle. This type of solid exists in the water leaving the WESP, the main source of water to the WWTP.

Solids that will settle are removed in the clarifier. As shown in Figure 6-2, the clarifier effluent, which contains floating and suspended solids, flows to the dissolved air flotation unit. In the dissolved air flotation unit, air is sparged into the water to produce very small air bubbles. These bubbles slowly rise through the water, and attach to any particle they contact. When one or more bubbles attaches to a suspended particle, the particle's buoyancy is increased and the particle floats to the surface. Solids and oils are continuously skimmed off the surface of the water in the dissolved air flotation unit.

Water leaving the dissolved air flotation unit passes through a sand filter to remove any residual suspended solids. After the sand filter, the water treatment is the same as that which was used in the Guam BCDP after the bag filters. The sand filter in the proposed system eliminates the need for the bag filters. The improved solids removal should eliminate the plugging of the oleophilic and carbon media with fines that was experienced at the Guam BCDP.

Day tanks are provided for storing the water in the proposed design. If excess water is generated, two tanks are required to store the water. After one tank is filled, the effluent is diverted to the second tank. The full tank is sampled and analyzed to insure that the treatment standards are met. When the tank is discharged, effluent can be switched back to the empty tank, and the second tank is sampled and analyzed. If the plant is a net water consumer, only one tank is necessary, and make-up water will have to be supplied.

WWTP Operation. The Guam BCDP was a net water user because of the large amount of water sprayed on the reactor product for dust suppression and to cool the product. As discussed earlier in this section, dust suppression and cooling of the reactor product in the next generation unit will probably be handled by more efficient methods that will use much less water. Water enters the BCDP process as steam from the boiler or moisture cooked off the soil. Non-process water streams include storm water and decontamination washdown water.

Moisture from the feed soil will probably be returned to the reactor product in the cooling and dust suppression step. The largest source of water added to the process is steam from the boiler. Using treated wastewater as boiler feed water would eliminate this water as a wastewater stream. Since most of the wastewater is condensate, the quality should be acceptable for use as boiler feed water. The boiler blowdown could not be added to the wastewater plant because it would be very high in suspended solids. The blowdown would have to be isolated and checked for PCBs before being discharged into the sewer. Alternatively, the blowdown could be sprayed on the contaminated soil prior to processing.

Non-process water flows (decontamination and storm water flows) must be estimated on a site-specific basis. Treated water could be used for decontamination, and careful design should minimize the amount of storm water requiring treatment. If recycle water can be used for boiler feed water, a zero water discharge plant should be possible. Sufficient carbon treatment would have to be done to remove the non-PCB organics if the treated water is used as boiler feedwater, and this would increase water carbon usage.

6.2.6 Minimizing Residuals

No attempt was made to process the cyclone fines or filter cake in the RKR, but this would have probably resulted in a reduction of residuals, especially the reprocessing of filter cake. Even if a percentage of the reprocessed filter cake returned to the system as fines, most of the fines would be collected as dry cyclone fines instead of wet filter cake. The filter cake is not dusty and could be added directly to the feed soil.

No testing of the effects of different RKR sweep gas flows on fines production was done on the Guam unit. The initial sweep gas flow was about 105 pounds an hour of steam and that flow was maintained throughout the project. Lowering the sweep gas flow would reduce the gas velocity through the kiln and should reduce the quantity of fines being swept out of the kiln. A minimum

sweep gas velocity is required to remove the PCBs being driven off the soil. A velocity higher than this minimum only increases the quantity of contaminated residuals.

Acid was effective in reducing the quantity of residuals on Guam because the soil was high in coral (which is soluble in acid). This should be tested on other sites to see if significant quantities of the residuals being generated are acid soluble. If treated wastewater is used as boiler feed water, soluble salt added to the water by this acid addition could be a problem. The effectiveness of acid addition must be evaluated on a site-specific basis.

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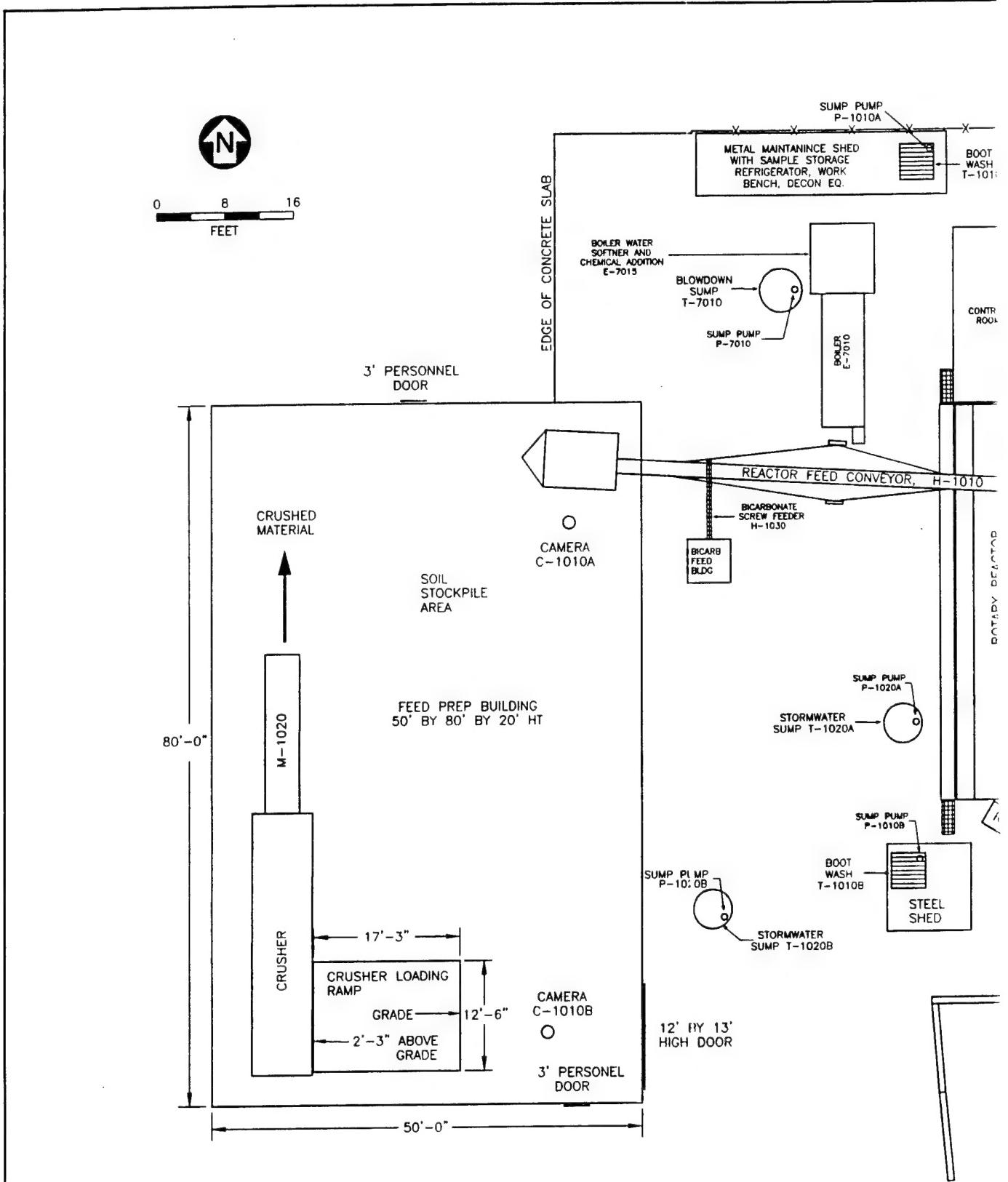
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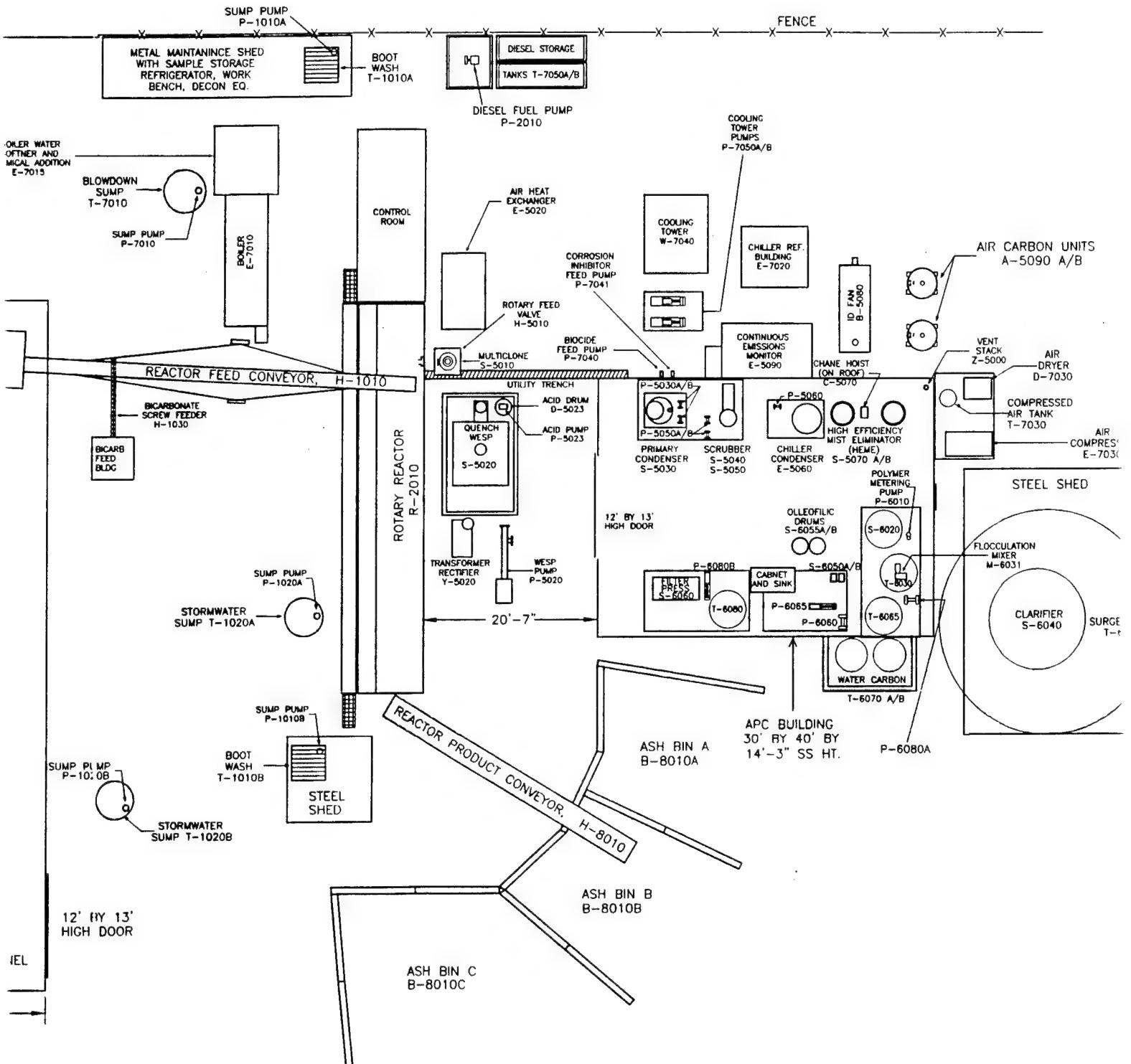
APPENDIX A

**PLOT PLAN, PROCESS FLOW DIAGRAM AND MATERIAL
BALANCE, AND PIPING AND INSTRUMENTATION DIAGRAMS**

PLOT PLAN



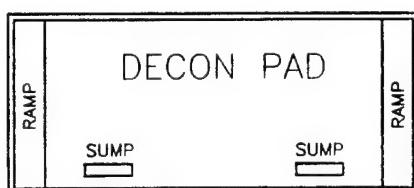
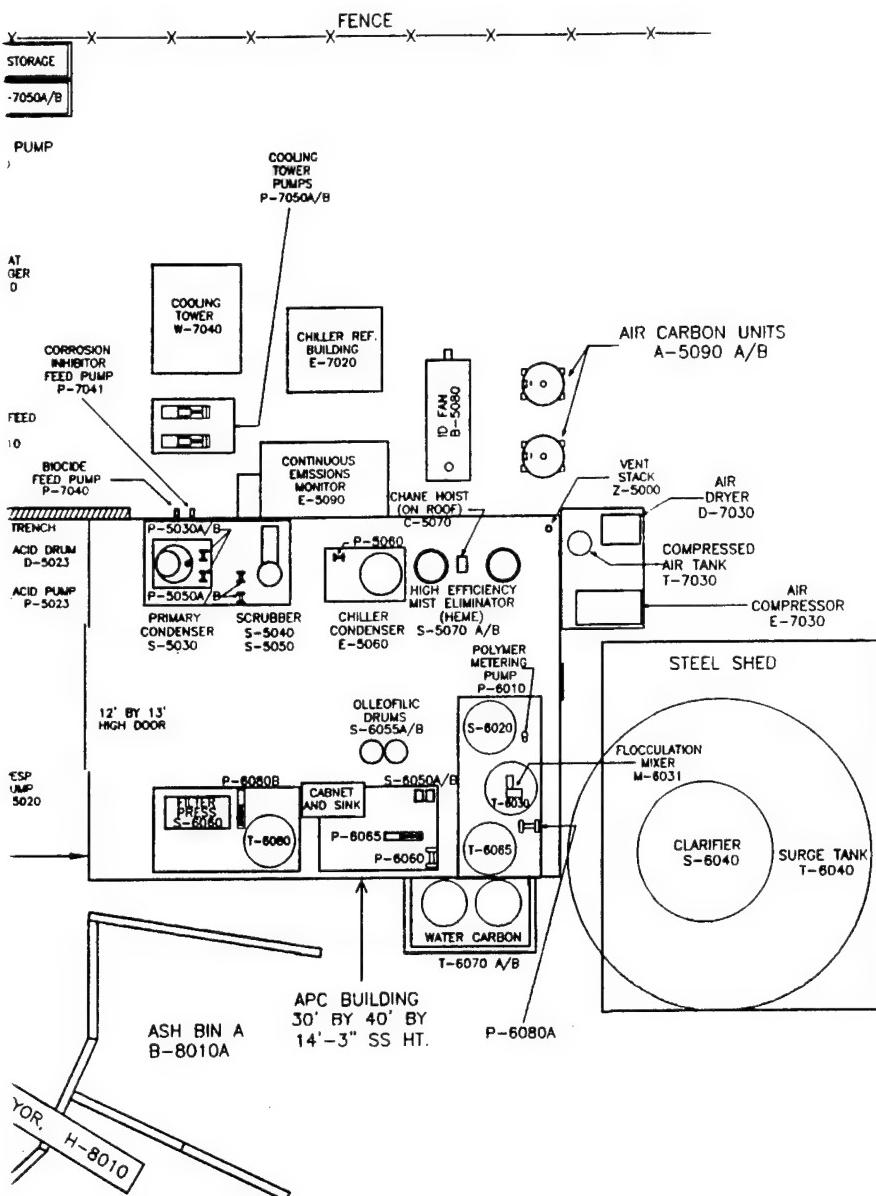
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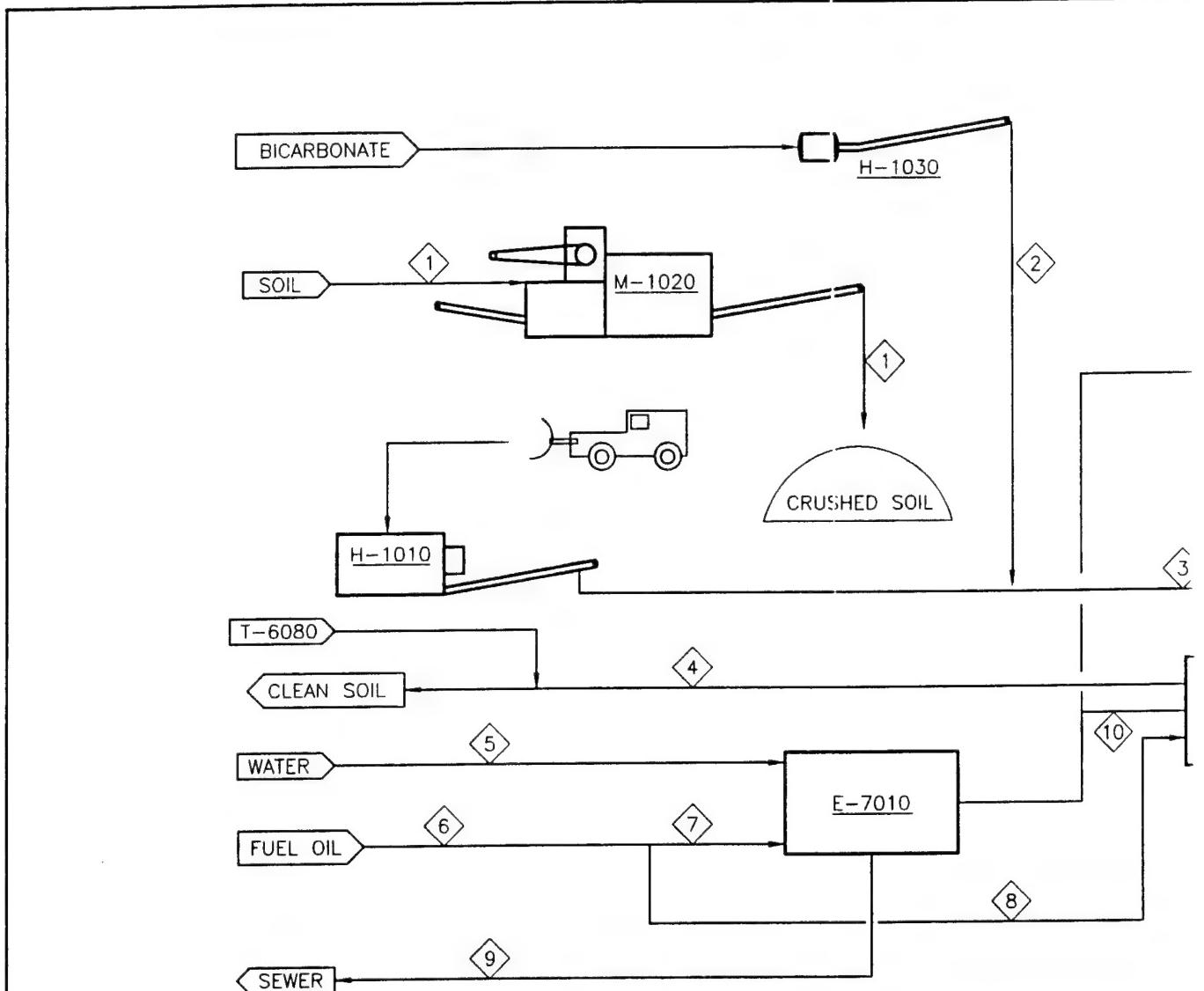
PLOT PLAN
NAVAL FACILITIES ENGINEERING
SERVICE CENTER
PREPARED FOR
BCDP
GUAM

PROJ. NO. 767877

SHT. 1 of 1

UNIQUE
NUMBER 767877-B1

PROCESS FLOW DIAGRAM AND MATERIAL BALANCE



H-1010
FEED CONVEYOR

M-1020
CRUSHER

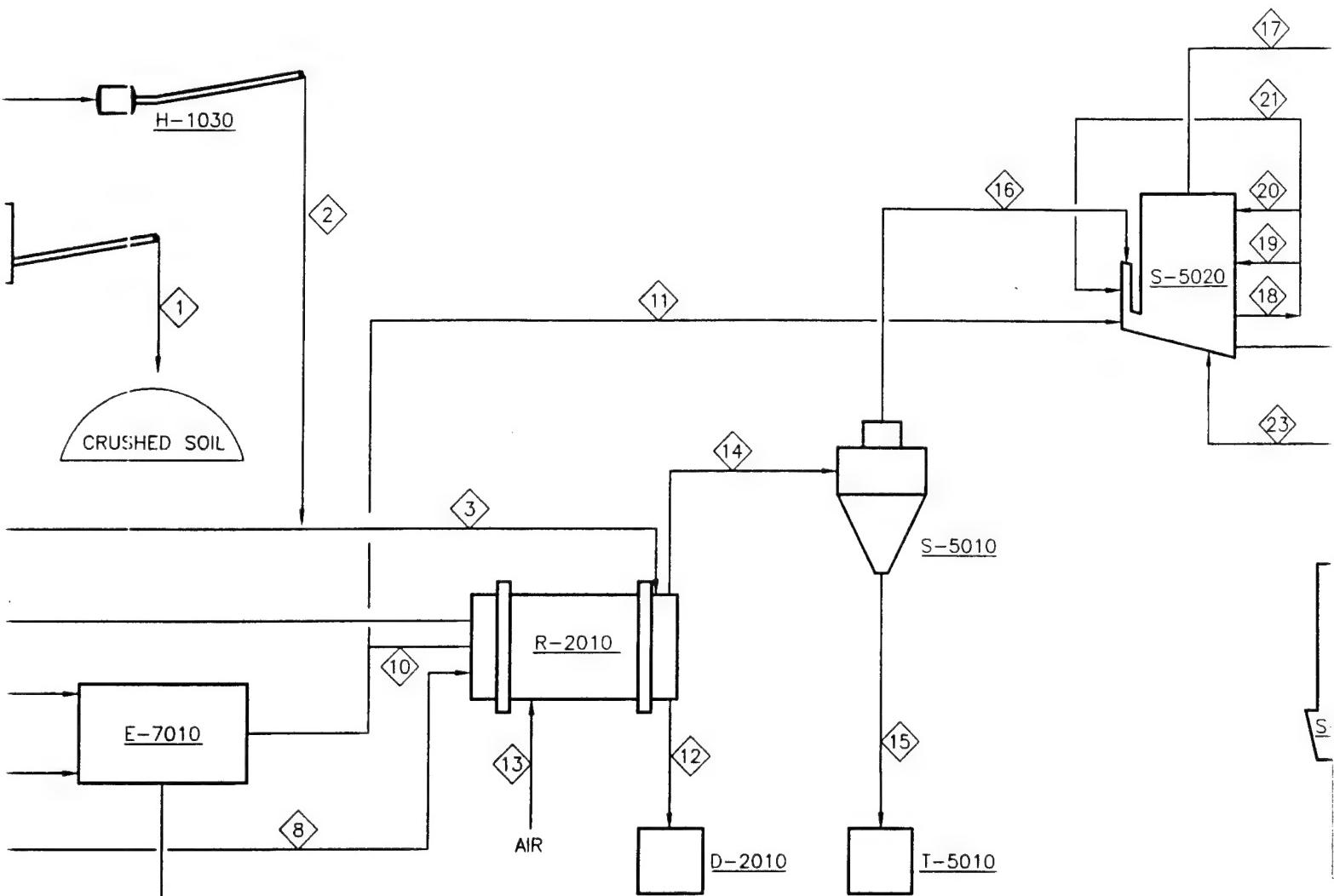
H-1030
BI-CARB FEEDER

E-7010
BOILER

R-
RO
F

STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	Br. Soil
STREAM NAME	Feed Soil	Sodium Bicarbonate	Feed Soil	Reactor Product	Boiler Feed Water	Fuel Oil	Fuel Oil To Boiler	Fuel Oil To Kiln	Boiler Blowdown	Steam to R-2010	Steam to Quench	Br. Soil
Dry Soil, lbs/hr	35,040		3,360	3,284								
Sodium Bicarb, lbs/hr		38.8	38.8									
Sodium Carbonate, lbs/hr				21.6								
Water, lbs/hr	4,800		466		373					10	105	258
Nitrogen, lbs/hr												
Oxygen, lbs/hr												
Carbon dioxide, lbs/hr												
Fuel oil, GPH						20.2	4.6	15.6				
Organics, lbs/hr	152		14.7									0
PCB, lbs/hr	8		0.776									0
Polymer, lbs/hr												
Total, lbs/hr	40,000	38.8	3,880	3,305	373					10	105	258
Design Max. lbs/hr					920					20	300	600
Degrees F	90		90	560	80					210	244	244
Pressure, in. WC gage											16 psig	16 psig
GPM					0.745					0.0200		
ACFM										46.9		115

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H-1030
CARB FEEDER

E-7010
BOILER

R-2010
ROTARY KILN
REACTOR

D-2010/T-5010
DUST RECEIVER

S-5010
MULTI-CLONE

S-5020
QUENCH/WESP

6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23				
fuel oil	Fuel Oil To Boiler	Fuel Oil To Kiln	Boiler Blowdown	Steam to R-2010	Breach Soil Drop	Infiltration Air	Kiln Off Gas	Multiclonel Dust	Multiclonel Off Gas	WESP Off Gas	WESP Recycle	WESP Nozzles	Deluge Wash	Quench Water	WESP Blowdown	Wt Mat					
					64.1		12.1	7.95	4.15	0.0208	44.9	29.9		15.0	4.29	0					
					0.74																
							2.40	1.58	0.822		26.8	17.9		8.94	2.56	1					
							66	571	571	523	22,518	15,012		7,506	2,152	1					
							66		66	66											
							20.2	8	8	8											
								32.0	32.0	32.0											
1.2	4.6	15.6																			
							0.281	1.66	0.00795	1.65	0.957	20.3	13.5	6.76	1.94	1					
							0.0148	0.761	0.0533	0.708	0.137	6.08	4.05	2.03	0.581	0.0					
							10	105	258	694	9.59	684	630	22,616	15,077	0	7,539	2,161	1		
							20	300	600						40000						
							210	244	244	90	407		340	205.9	200	200	200	200			
								16 psig	16 psig	-0.44		-0.79			45	30	0	15	4.3	3	
								0.0200													
									46.9	115		370	341	262							

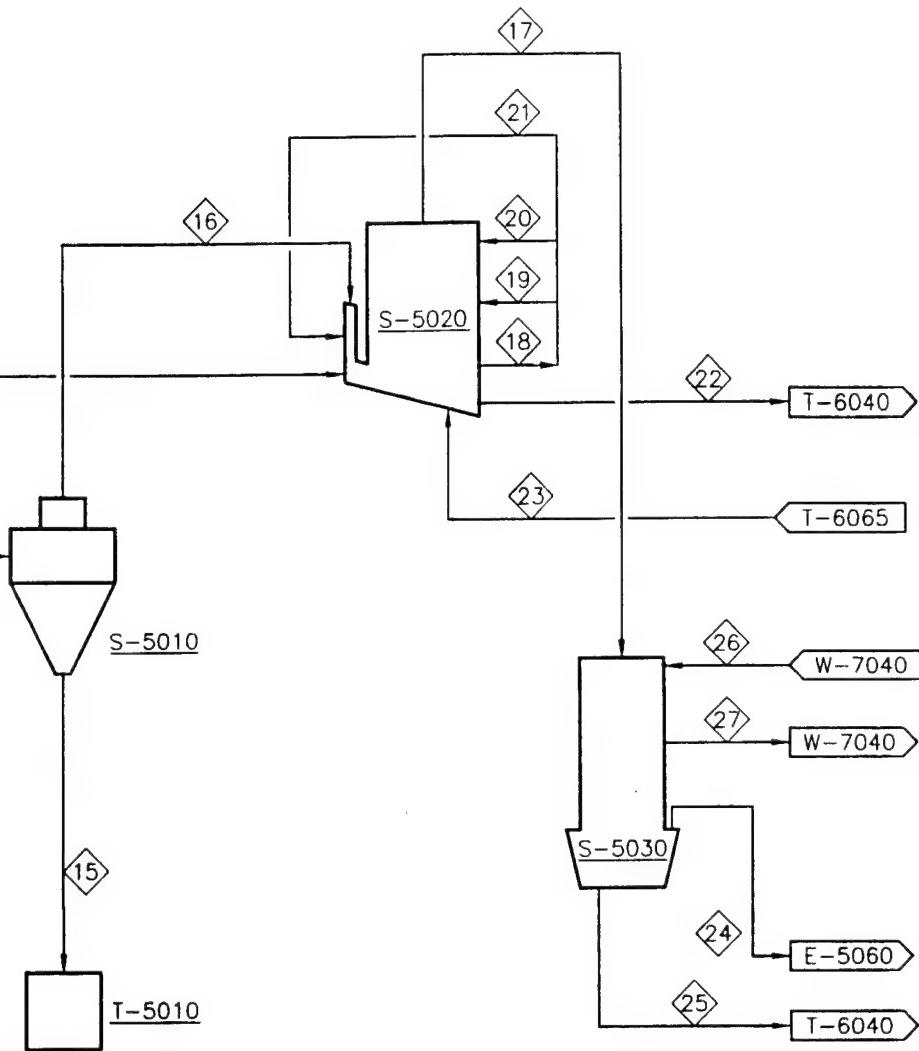
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GUAM



10/T-5010

T RECEIVER

S-5010

MULTI-CLOWN

S-5020

QUENCH/WESP

S-5030

PRIMARY CONDENSER

16	17	18	19	20	21	22	23	24	25	26	27	
Multiclon Off Gas	WESP Off Gas	WESP Recycle	WESP Nozzles	Deluge Wash	Quench Water	WESP Blowdown	WESP Make Up	P. Cond. Off-Gas	P. Cond. Blow Down	CTW into P.C.	CTW Out of P.C.	
4.15	0.0208	44.9	29.9		15.0	4.29	0.157		0.0208			
0.822		26.8	17.9		8.94	2.56	1.74					
571	523	22,518	15,012		7,506	2,152	1,845	2.44	520			
66	66							66				
8	8							8				
32.0	32.0							32.0				
1.65	0.957	20.3	13.5		6.76	1.94	1.24	0.26	0.697			
0.708	0.137	6.08	4.05		2.03	0.581	0.00969	0.0228	0.114			
684	630	22,616	15,077	0	7,539	2,161	1,849	109	521			
				40000								
340	205.9	200	200		200	200	90	80	80	79	90	
-0.79								-0.82		40 psig	40 psig	
		45	30	0	15	4.3	3.69		1.04	200	200	
341	262							22.8				

PROCESS FLOW DIAGRAM
NAVAL FACILITIES ENGINEERING
SERVICE CENTER

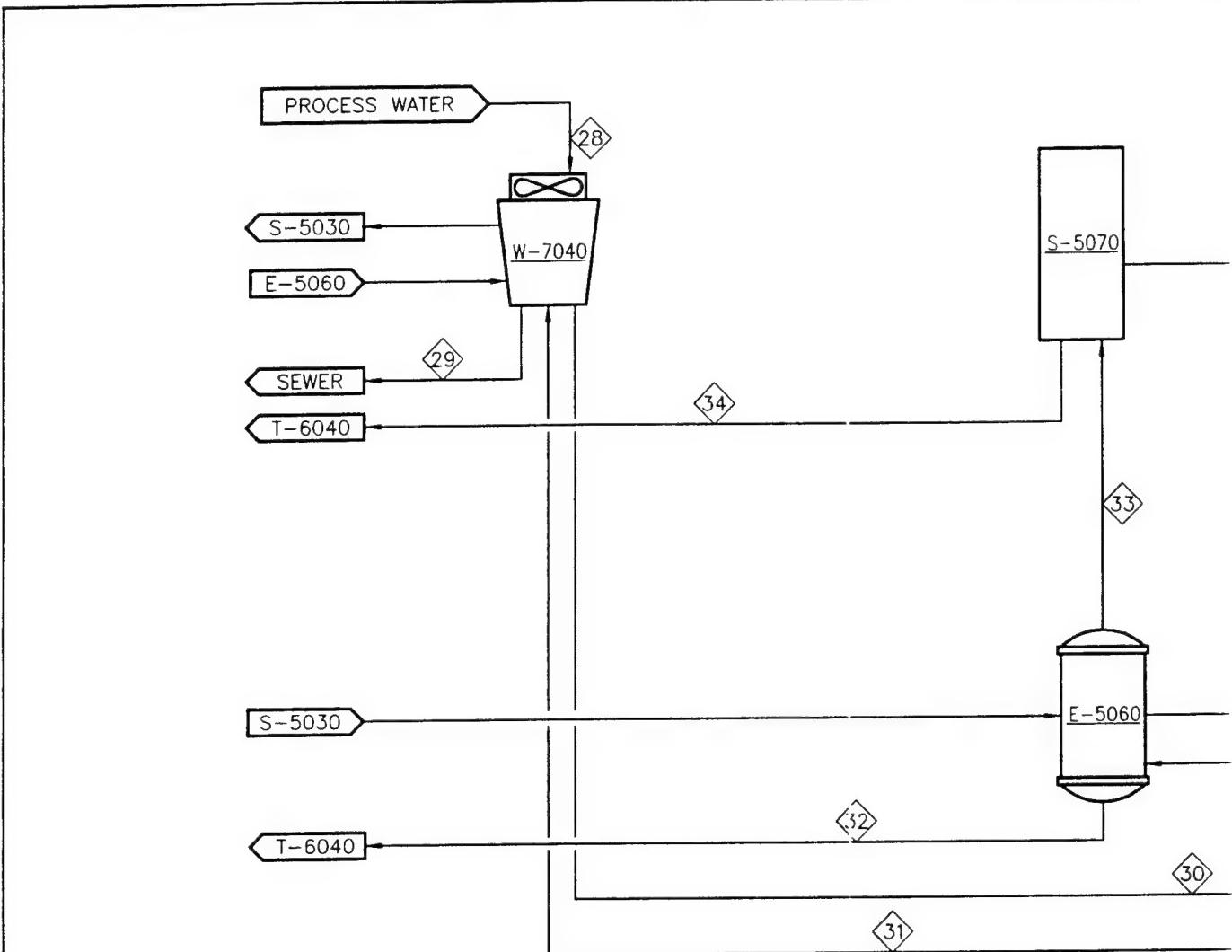
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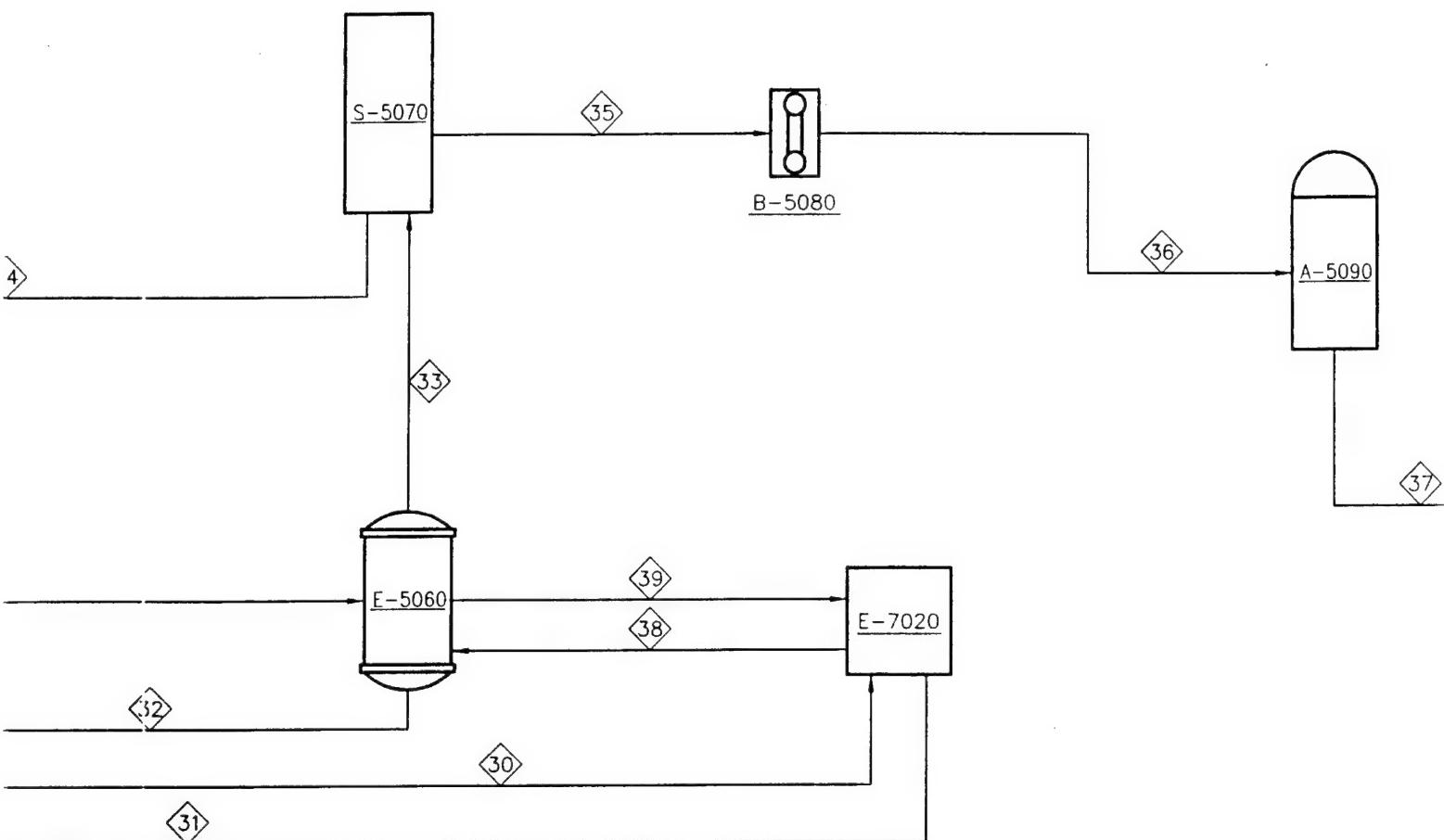


W-7040
COOLING TOWER

S-5070
HIGHT EFF. MIST
ELIMINATOR
(HEME)

E-5060
CHILLER CONDENSE

STREAM NUMBER	28	29	30	31	32	33	34	35	36	37	38	39
STREAM NAME	CT Water Make Up	CT Blow- Down	CTW to E-7020	CTW From E-7020	E-5060 Drain	E-5060 Off-Gas	HEME Drain	HEME Off-Gas	ID Fan Off-Gas	Carbon Off-Gas	Chilled Glycol Sol.	Chilled Glycol Sc
Dry Soil, lbs/hr												
Sodium Bicarb, lbs/hr												
Sodium Carbonate, lbs/hr												
Water, lbs/hr					1.48	0.958		0.958	0.958	0.958		
Nitrogen, lbs/hr						66		66	66	66		
Oxygen, lbs/hr						8		8	8	8		
Carbon dioxide, lbs/hr						32.0		32.0	32.0	32.0		
Fuel oil, GPH												
Organics, lbs/hr						0.26		0.26	0.26	0.26		
PCB, lbs/hr						0.0228	0.0228					
Polymer, lbs/hr												
Total, lbs/hr					1.48	107	0.0228	107	107	107		
Design Max. lbs/hr											91	32
Degrees F	90	79	79			50					32	33
Pressure, in. WC gage				40 psig	40 psig		-1.8		-2.06			
GPM	2.5	1	80	80							80	80
ACFM								19.0	19.0	22.7		
1	REVISION											
0	REVISION											
NO.	REVISION	BY	DATE	CHK'D APRYD	PROJ. MGR.							



S-5070

HIGHT EFF. MIST
ELIMINATOR
(HEME)

E-5060

CHILLER CONDENSER

B-5080

BLOWER

E-7020

REFRIGERATION
SYSTEM

A-5090

GRANULAR CARBOI

	34	35	36	37	38	39
50	HEME	HEME	ID Fan	Carbon	Chilled	Chilled
51	Drain	Off-Gas	Off-Gas	Off-Gas	Glycol Sol.	Glycol Sol.
52						
53						
54	0.958	0.958	0.958			
55	66	66	66			
56	8	8	8			
57	32.0	32.0	32.0			
58	0.26	0.26	0.26			
59	0.0228					
60	0.0228	107	107	107		
61						
62	-2.06			91	32	33
63					80	80
64	19.0	19.0	22.7			

STARTING DATE: 10/95

DATE LAST REV: 10/16/97

DATE:

DATE:

DATE:

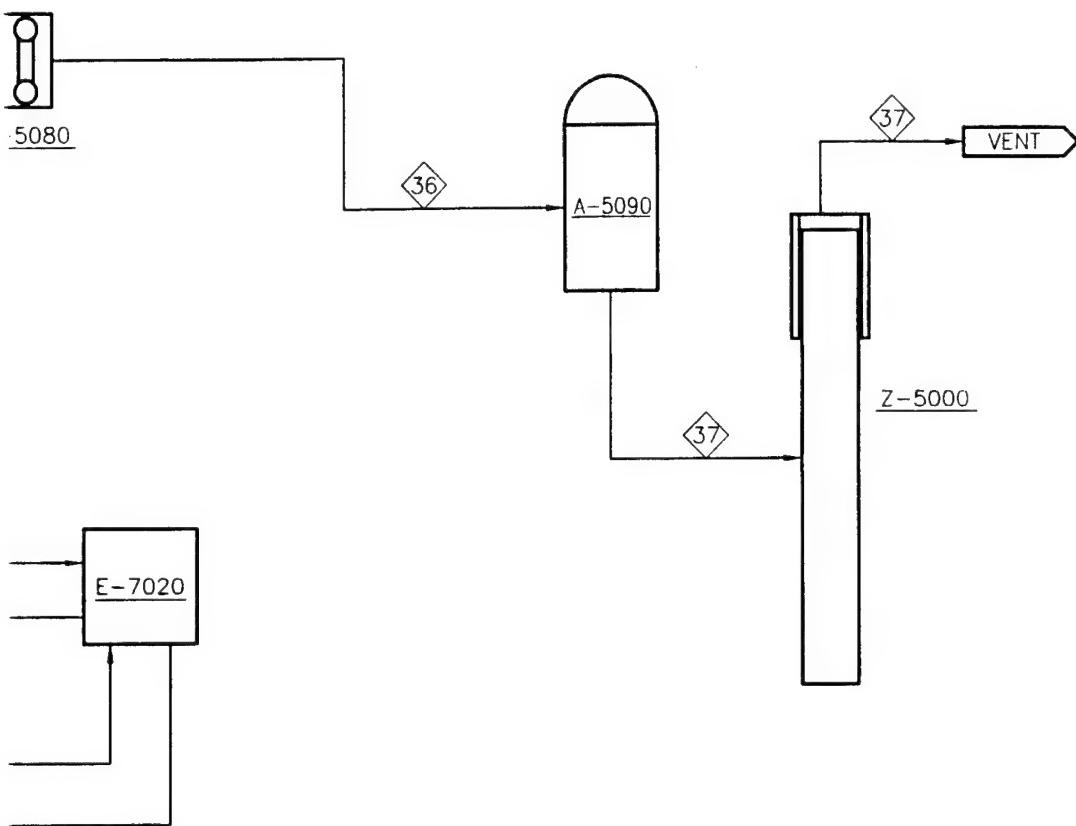
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8

PROCESS FLOW
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GUAM



80
R

E-7020
REFRIGERATION
SYSTEM

A-5090
GRANULAR CARBON

Z-5000
STACK

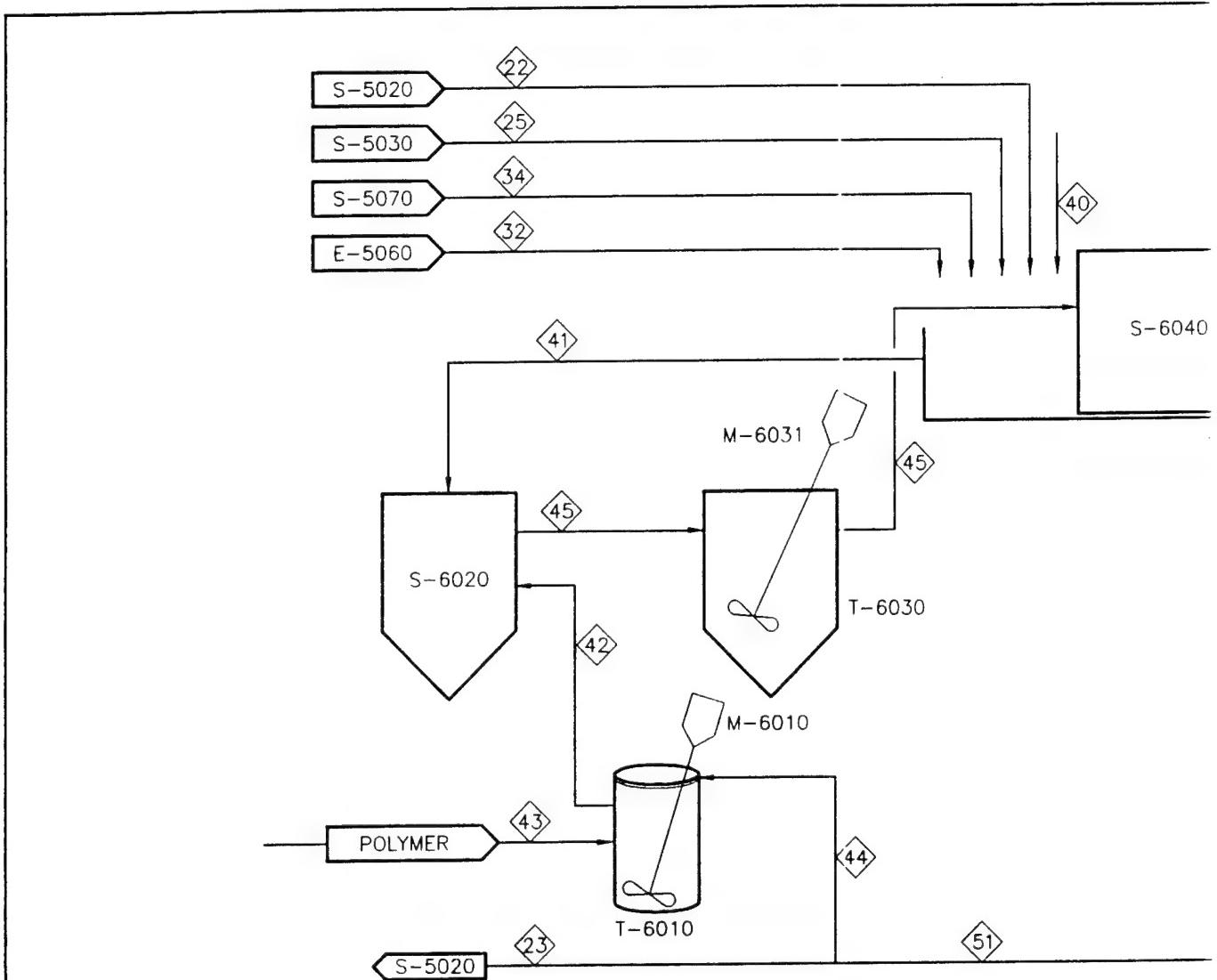
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PROCESS FLOW DIAGRAM
NAVAL FACILITIES ENGINEERING
SERVICE CENTER
PREPARED FOR
BCDP
GUAM

PROJ. NO. 767877

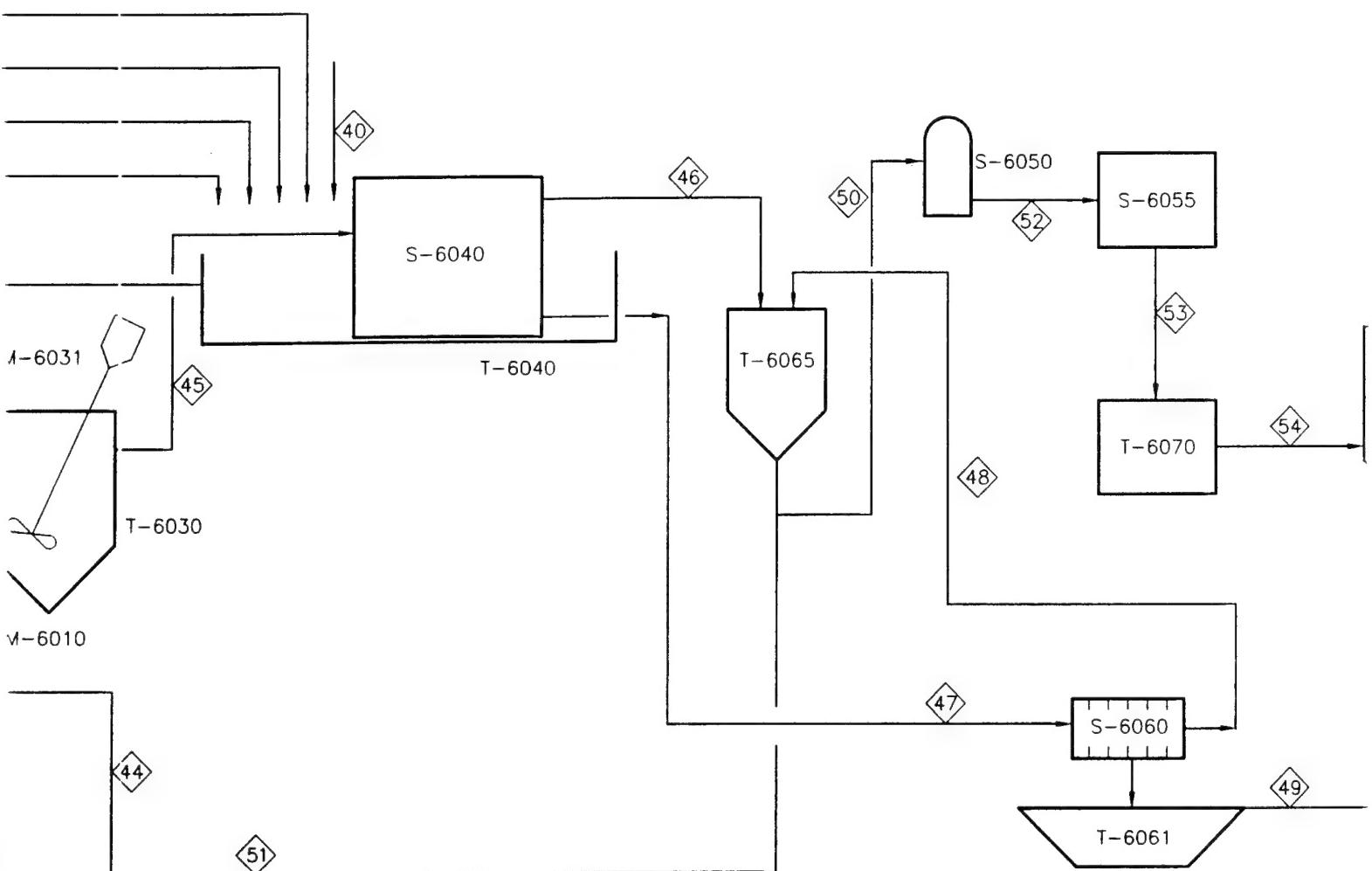
SHT. 2 of 3

UNIQUE
NUMBER 767877-B3



S-6020 **T-6010** **T-6030** **S-6040** **T-6065**
 OIL-WATER POLYMER FLOC CLARIFIER CLARIFIED
 SEPARATOR TANK MIX/FEED TANK TANK WATER TANK

STREAM NUMBER	40	41	42	43	44	45	46	47	48	49	50	51
STREAM NAME	Decon/stm Water	WWTP Feed	Polymer Solution	Polymer	Process Water	Clarifier Feed	Clarifier Effluent	Clarifier Sludge	Filtrate	Filter Cake	Water to Bag Filter	Process Water
Dry Soil, lbs/hr		4.31				4.31	0.231	4.08	0	4.08	0.0740	0.157
Sodium Bicarb, lbs/hr						0						0
Sodium Carbonate, lbs/hr		2.56				2.56	2.44	0.127	0.123	0.00321	0.82	1.74
Water, lbs/hr	50.0	2,723	7.19		7.19	2,731	2,595	136	132	4.31	874	1,853
Nitrogen, lbs/hr												
Oxygen, lbs/hr												
Carbon dioxide, lbs/hr												
Fuel oil, GPH												
Organics, lbs/hr		2.64				2.64	1.83	0.810		0.810	0.585	1.24
PCB, lbs/hr		0.718				0.718	0.0143	0.703		0.703	0.00457	0.00969
Polymer, lbs/hr			0.73	0.73		0.73		0.73		0.73		
Total, lbs/hr	50.0	2,734	7.92	0.73	7.19	2,741	2,599	142	132	10.6	875	1,856
Design Max. lbs/hr												
Degrees F		90				90						
Pressure, in. WC gage		0										
GPM	0.1	5.44				5.44	5.19	0.272			1.75	3.70
ACFM		0										
						DRAWN BY:	WEG	STARTING DATE:	10/95			
						REVISED BY:	RPS	DATE LAST REV:	10/3/97			
						INITIATOR:		DATE:				
						DRAFT. CHK.:		DATE:				
1	REVISION					ENG. CHK.:		DATE:				
0	REVISION											
NO.	REVISION	BY	DATE	CHK'D	APR'D	PROJ. MGR.:		DATE:				



6030
FLOC
TANK

S-6040
CLARIFIER

T-6065
CLARIFIED
WATER TANK

S-6050
BAG FILTER

S-6055
OLEOFILIC MEDIA

C-6070
CARBON BED

S-6060
FILTER
PRESS

T-6061
HOPP

46	47	48	49	50	51	52	53	54	55	56
Clarifier Effluent	Clarifier Sludge	Filtrate	Filter Coke	Water to Bag Filter	Process Water	Water to Oleo.	Water to Carbon	Treated Water	Potable Water	Water to RKR Prod.
0.231	4.08	0	4.08	0.0740	0.157	0.0370	0.0185			
					0					
2.44	0.127	0.123	0.00321	0.82	1.74	0.82	0.82	0.82		0.82
2,595	136	132	4.31	874	1,853	874	874	874	2,502	3,376
1.83	0.810		0.810	0.585	1.24	0.585	0.293			
0.0143	0.703		0.703	0.00457	0.00969	0.00228	0.00114			
	0.73		0.73							
2,599	142	132	10.6	875	1,856	875	875	874	2,502	3,376
5.19	0.272			1.75	3.70	1.75	1.75	1.75	5	6.75

STARTING DATE: 10/95

DATE LAST REV: 10/3/97

DATE:

DATE:

DATE:

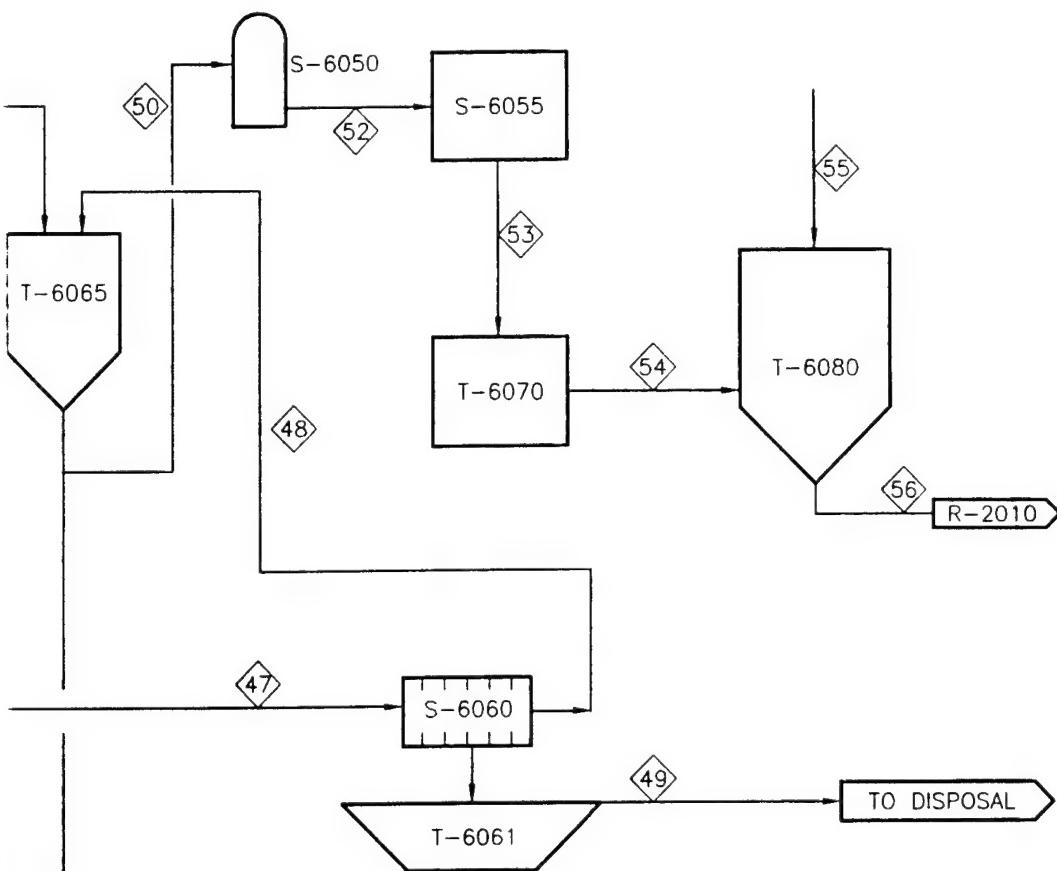
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(2)

PROCESS FLOW
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GUAM



S-6055
EOFILIC MEDIA

C-6070
CARBON BED

S-6060
FILTER PRESS

T-6061
FILTER CAKE HOPPER

T-6080
TREATED WATER SUPPLY TANK

55	56
Potable Water	Water to RKR Prod.
0.82	
2,502	3,376
2,502	3,376
5	6.75

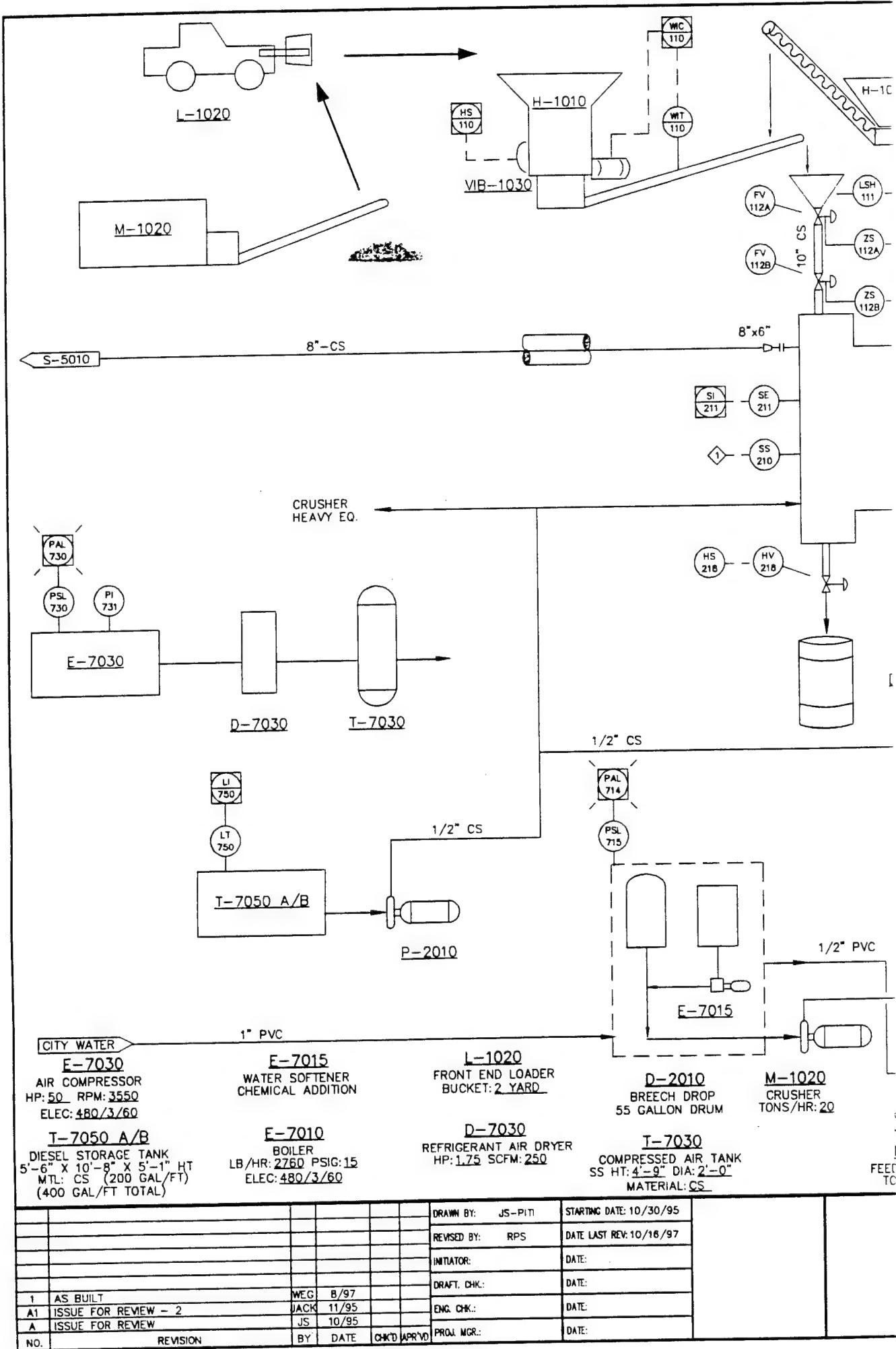
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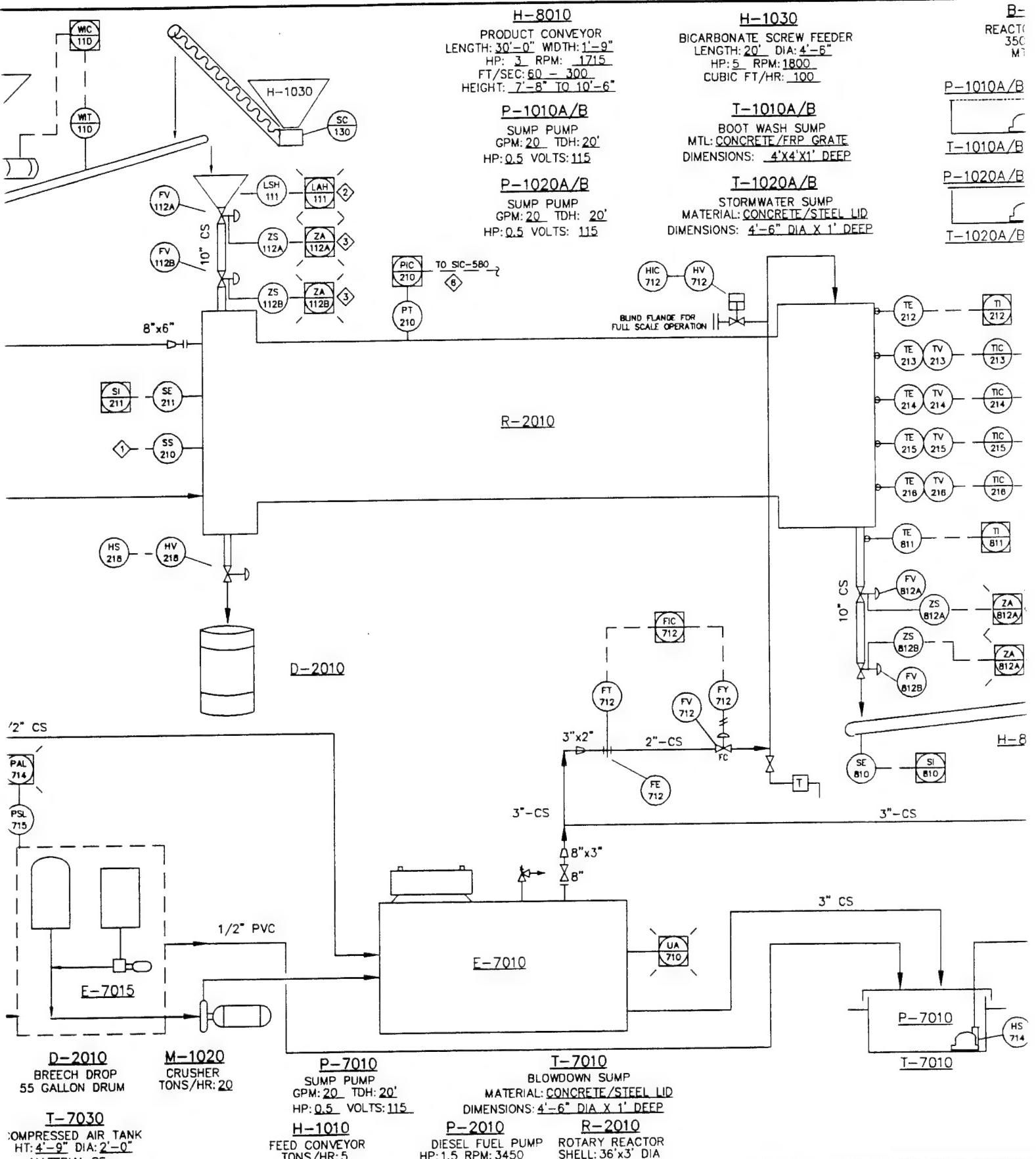
PROCESS FLOW DIAGRAM
NAVAL FACILITIES ENGINEERING
SERVICE CENTER
PREPARED FOR
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GUAM

PROJ. NO. 767877

SHT. 3 of 3

UNIQUE NUMBER 767877-B4





MTX-AB/7B/05

1991-1993/03

P-7010
SUMP PUMP
GPM: 20 TDH: 20'
HP: 0.5 VOLTS: 115

H-1010
FEED CONVEYOR
TONS/HR: 5

H-1010 P-2010 R-2010
FEED CONVEYOR DIESEL FUEL PUMP ROTARY REACTOR
TONS/HR: 5 HP: 1.5 RPM: 3450 SHELL: 36'x3' DIA

H-1010 P-2010 R-201

FEED CONVEYOR **DIESEL FUEL PUMP** **ROTARY REACTOR**
TONS/HR: 5 **HP: 1.5 RPM: 3450** **SHELL: 36'x3' DIA**

PIPING AND INSTRUMENTATION REACTOR

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BCDP
CHAM

H-8010

PRODUCT CONVEYOR
H: 30'-0" WDT: 1'-9"
HP: 3 RPM: 1715
T/SEC: 60 - 300
GHT: 7'-8" TO 10'-6"

P-1010A/B

SUMP PUMP
GPM: 20 TDH: 20'
HP: 0.5 VOLTS: 115

P-1020A/B

SUMP PUMP
GPM: 20 TDH: 20'
HP: 0.5 VOLTS: 115

H-1030

BICARBONATE SCREW FEEDER
LENGTH: 20' DIA: 4'-6"
HP: 5 RPM: 1600
CUBIC FT/HR: 100

T-1010A/B

BOOT WASH SUMP
MTL: CONCRETE/FRP GRATE
DIMENSIONS: 4'X4'X1' DEEP

T-1020A/B

STORMWATER SUMP
MATERIAL: CONCRETE/STEEL LID
DIMENSIONS: 4'-6" DIA X 1' DEEP

B-8010 A/B

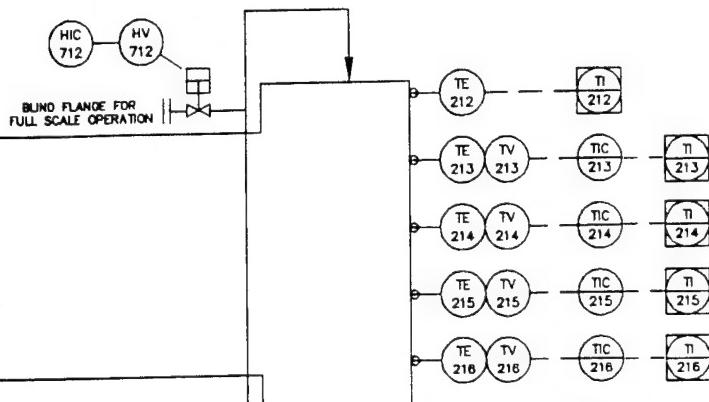
REACTOR PRODUCT BIN
350 SF X 5' HT.
MTL: CONCRETE

B-8010 C

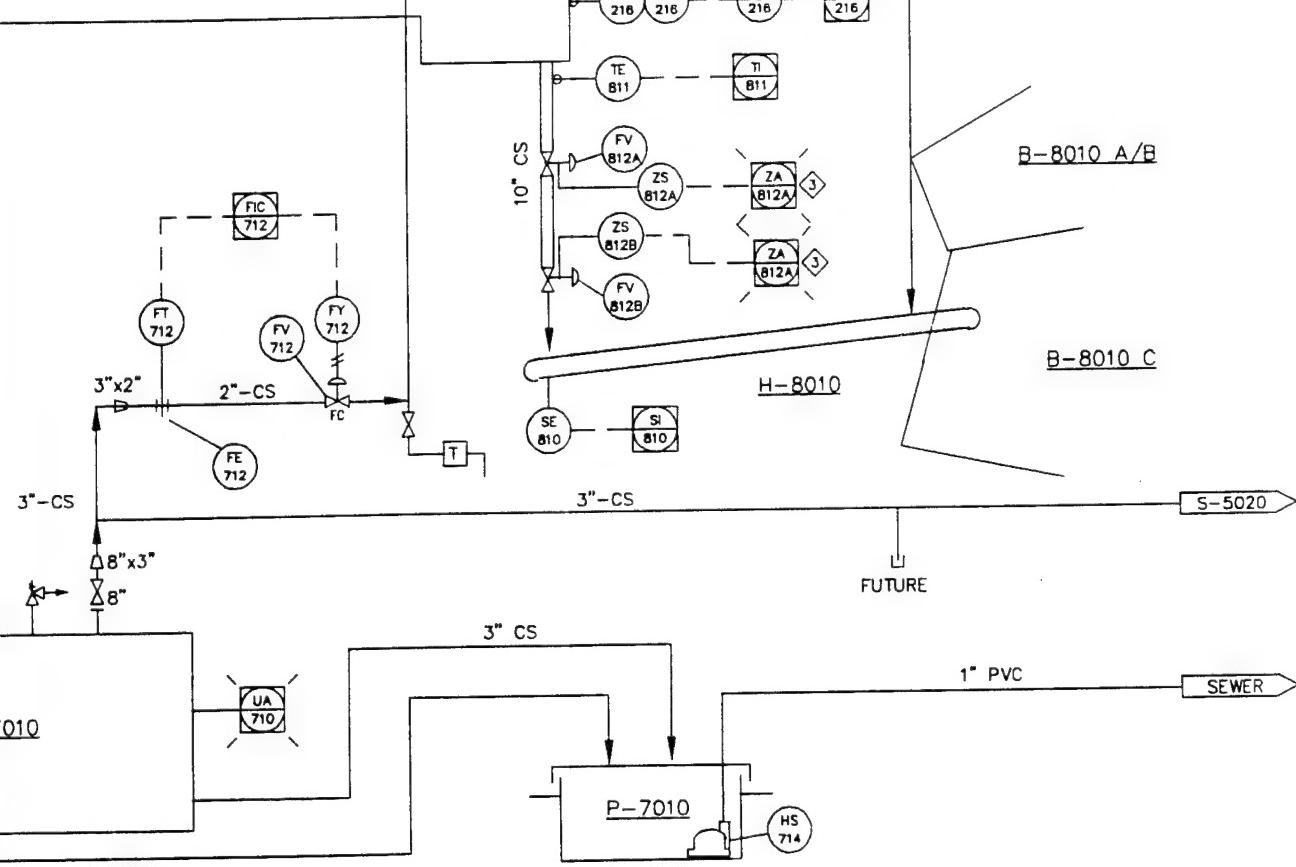
WEEKEND BIN
508 SF X 5' HT
MTL: CONCRETE



0



R-2010

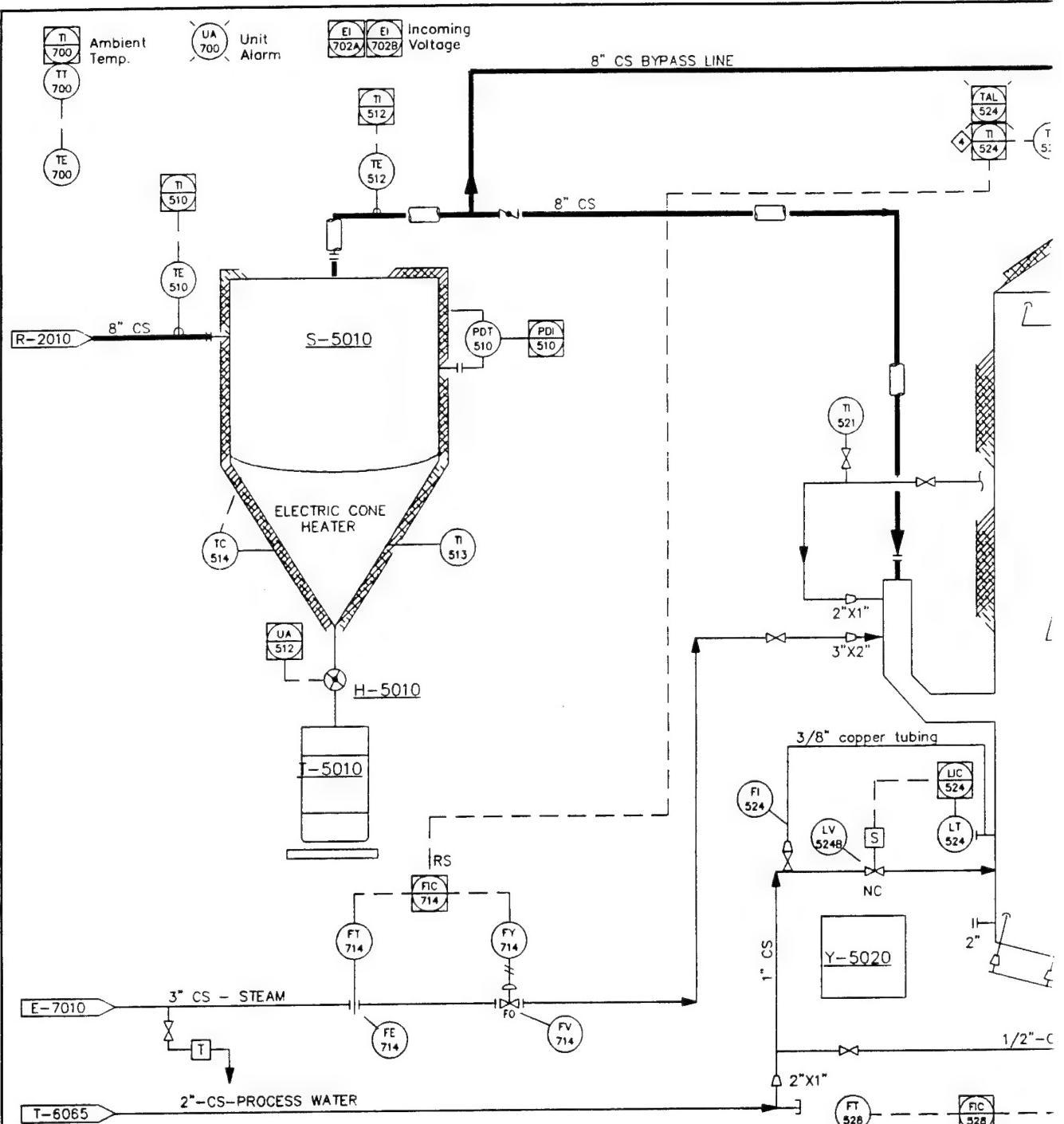


T-7010

BLOWDOWN SUMP
MATERIAL: CONCRETE/STEEL LID
DIMENSIONS: 4'-6" DIA X 1' DEEP

JEL PUMP ROTARY REACTOR
SHELL: 36'X3' DIA
1:3450

R-2010



E-5020
 AIR HEAT EXCHANGER
 TUBE SF: 151 TOTAL SF: 2399
 HP: 5 RPM: 1800
 ELEC: 460/1/60

S-5010

S-5020
 WET ELEC. PPT.
 MTL: 316LSS AREA: 773 SF
 No. TUBES: 82 DIA: 6"
 DIMENSIONS: 6'X7'X23' HT

P-5023
 ACID METERING PUMP
 GPH: 0.4 PSIG: 140
 AMPS: 0.10 VOLTS: 115

T-5010
 TRANSFORMER RECTIFIER
 INPUT: VAC 480 AAC 54
 OUTPUT: KVDC 45 mADC 400
 POWER, KVA: 25.6
 ELEC: 460/1/60

H-5010
 ROTARY FEED VALVE
 FINE COLLECTION 55 GALLON DRUM

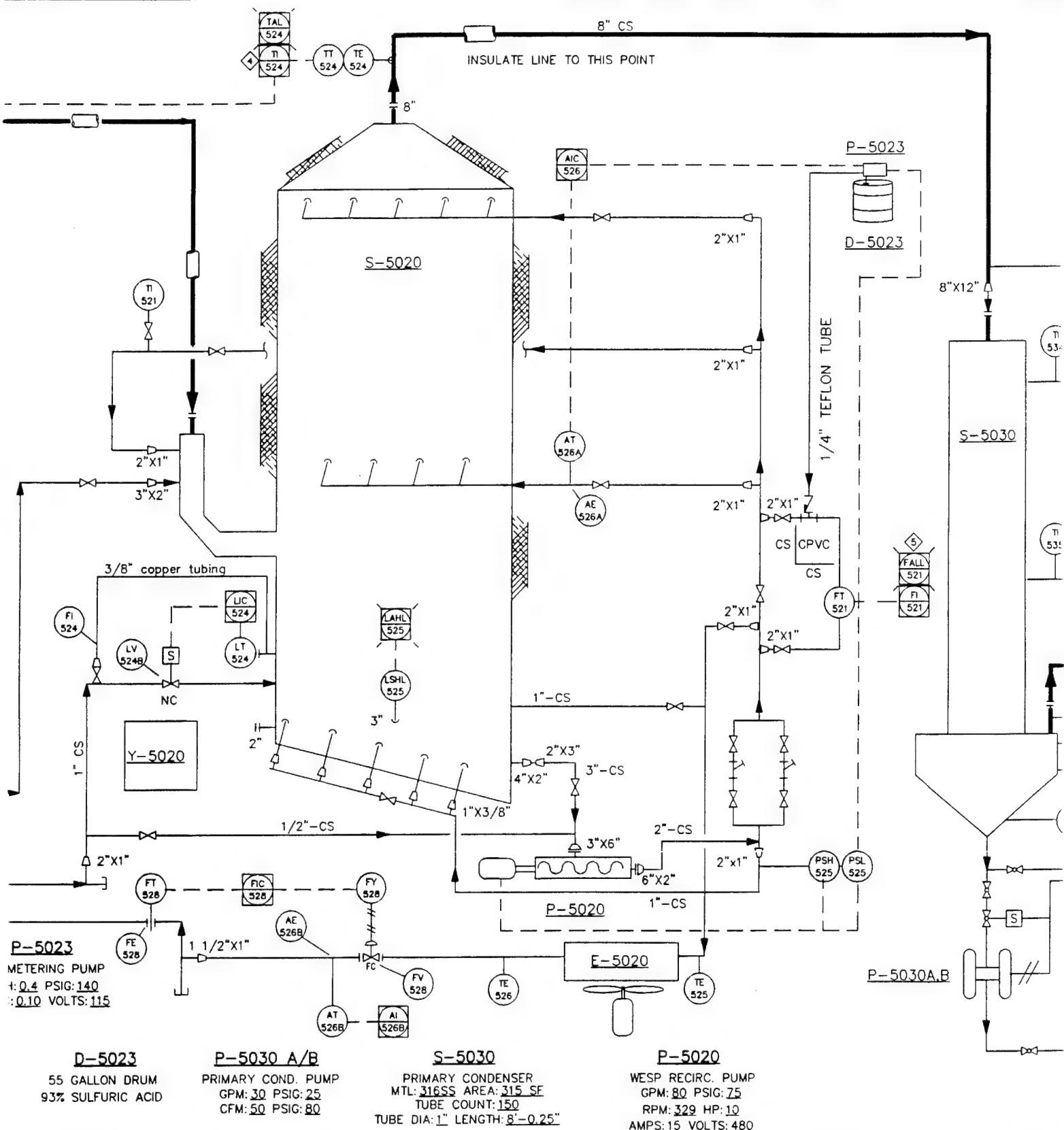
D-5023
 55 GALLON DRUM
 93% SULFURIC ACID

P-5030 A/B
 PRIMARY COND. PUI
 GPM: 30 PSIG: 25
 CFM: 50 PSIG: 80

				DRAWN BY: JS-PITI	STARTING DATE: 10/30/95	
				REVISED BY: RPS	DATE LAST REV: 10/16/97	
				INITIATOR:	DATE:	
				DRAFT. CHK.:	DATE:	
				ENG. CHK.:	DATE:	
				PROJ. MGR.:	DATE:	
1	AS BUILT	WEG	2/97			
0	ISSUE FOR CONSTRUCTION	JACK	11/95			
A	ISSUE FOR REVIEW	JS	10/95			
NO.	REVISION	BY	DATE	CHK'D APR'95	PROJ. MGR.:	

WESP KV   WESP
Shut Down

ASS LINE



D-5023

55 GALLON DRUM
93% SULFURIC ACID

P-5030 A/B
PRIMARY COND. PUMP
GPM: 30 PSIG: 25

S-5030
PRIMARY CONDENSER
MTL: 316SS AREA: 315 SF
TUBE COUNT: 150
TUBE DIA: 1" LENGTH: 8'-0.25"

P-5020
WESP RECIRC. PUMP
GPM: 80 PSIG: 75
RPM: 329 HP: 10
AMPS: 15 VOLTS: 480

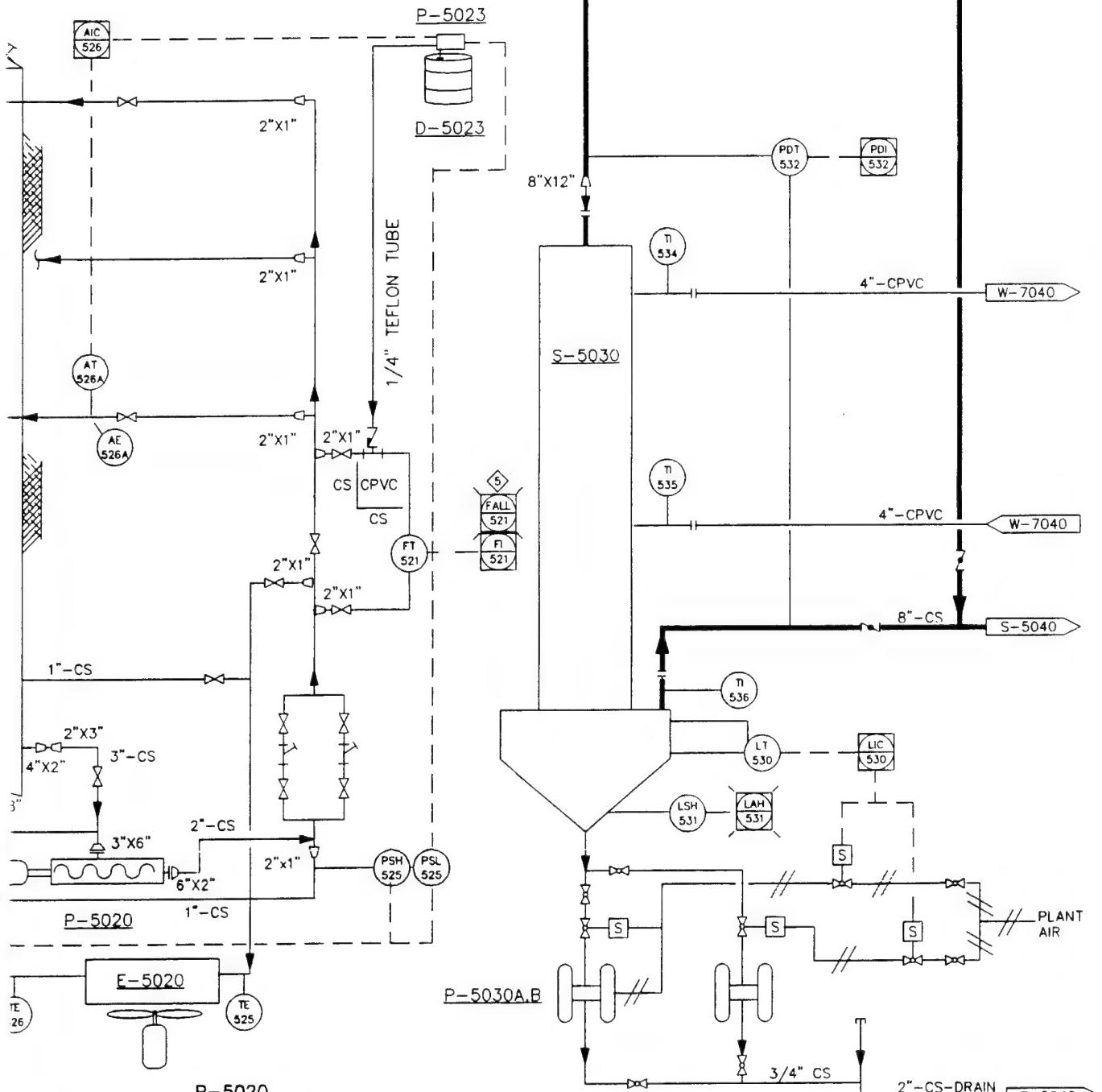
NG DATE: 10/30/95
AST REV: 10/16/97

**PIPING AND INSTRUMENTATION
GAS CONDITIONING
NAVAL FACILITIES ENGINEERING**

PREPARED FOR
BCDP
GUAM

8" CS

DATE LINE TO THIS POINT



NSER
315 SF
150
8-0.25"

WESP RECIRC. PUMP
GPM: 80 PSIG: 75
RPM: 329 HP: 10
AMPS: 15 VOLTS: 480

**PIPING AND INSTRUMENTATION DIAGRAM
GAS CONDITIONING
NAVAL FACILITIES ENGINEERING SERVICE CENTER**

PREPARED FOR
BCDP
GUAM

PROJ. NO. 767877

SHT. 2 of 6

UNIQUE
NUMBER 767877-B6

PROCESS FLOW DIAGRAM MATERIAL BALANCE CALCULATIONS

Introduction

This report gives the basis for the numbers in the material balance. Where possible, recorded data are used. Assumptions and data used are stated in the discussion of individual flow streams.

Data Used in the Material Balance

The material balance is based on the following items:

- A. Operating data during the stack test that occurred June 18 between 12:30 and 21:00 hours. Operating data on June 18 are in Appendix C. Stack test data for the period are in Appendix F. Appendix G shows that the feed soil was 150 parts per million (ppm) polychlorinated biphenyl (PCB) at 12 percent (%) moisture and the reactor product was less than 0.5 ppm per PCB congener.
- B. The U.S. Environmental Protection Agency (EPA) conducted a sampling study at the site in February 1997 to determine the fate of PCBs in the overall system. At the time of this writing that study had not been published, but preliminary data were available. Until the final study is published, this preliminary data is the best information available.

The operating data (Appendix C) is the source of the pressure and temperature data on the Process Flow Diagram (PFD).

Equations Used

Flows in actual cubic feet per minute (acf m) are given for gas streams. These flows are calculated using the ideal gas law. One mole of gas at 32 degrees Fahrenheit ($^{\circ}$ F) and atmospheric pressure occupies 359 cubic feet. Pressures in the off-gas system are close enough to atmospheric pressure that they are assumed to be atmospheric. The temperature correction is made.

As an example, the RKR off-gas (Stream 14) contains 571 pounds per hour (lbs/hr) of water, 66 lbs/hr of nitrogen, 8 lbs/hr of oxygen, 32 lbs/hr of carbon dioxide, and 25.3 lbs/hr of organics at 407 $^{\circ}$ F. The organics are assumed to have a molecular weight of 100. The flow is calculated as follows:

H ₂ O:	571/18 = 31.7 moles
N ₂ :	66/28 = 2.36 moles
O ₂ :	8/32 = 0.25 moles
CO ₂ :	32/44 = 0.73 moles
Organics:	25.3/100 = 0.25 moles

Adding, the total number of moles is 35.31. At 32°F, this gas has a volume of:

$$35.31 \text{ moles} * 359 \text{ ft}^3/\text{mole} = 12,677 \text{ ft}^3$$

The volume is then corrected to 407°F:

$$12,778 \text{ ft}^3 * (407 + 460)^\circ \text{ R} / (32 + 460)^\circ \text{ R} = 22,340 \text{ ft}^3$$

Divide by 60 to convert from hours to minutes:

$$22,340 \text{ ft}^3/60 = 372 \text{ acfm}$$

Another equation used that is based on the ideal gas law is:

$$\text{Gas Density, lbs/ft}^3 = (\text{Molecular Weight} * \text{psia}) / (10.72 + (T + 460))$$

where T is temperature in °F, psia is pressure in pounds per square inch absolute.

Stream Number 1 (Crusher)

The crusher throughput was not measured, but the crusher was rated at 20 tons per hour. The soil moisture and PCB content are from Item A. The organic content of the soil was not measured and is an assumption.

Stream Number 2 (Sodium Bicarbonate Addition)

No sodium bicarbonate was added during the June 18 stack test because the plant had run out. The material balance assumes an addition rate of 1%.

Stream Number 3 (RKR Feed)

The feed rate is from Item A.

Stream Number 12 (Breach Soil Drop)

This stream was measured during the EPA tests. Three runs were made and the average rate of soil dropping out here was 74 lbs/hr.

Stream Numbers 4, 13, and 14 (Around RKR)

These streams must be considered together.

Dry Soil. Dry soil either exits as product (Stream 4) or is carried out in the off-gas stream (Stream 14). The quantity that is carried out in Stream 14 is estimated based on residuals accumulations of multiclone fines and filter cake (solids that passed through the multiclone).

Based on the residuals inventory after 5,550 tons of soil had been processed, there were 22,740 pounds of multiclone fines and 23,805 pounds of filter press cake. Assume the cake is 50% moisture and all solids pass through the multiclone, then the material going to and passing through the multiclone, as a function of percent of feed, is:

$$\text{Multicloner fines} = 22,740 * 100 / (5,550 * 2,000) = 0.205\%$$
$$\text{Passing the Multicloner} = 23,805 * 100 * 0.50 / (5,550 * 2,000) = 0.107\%$$

Thus for a soil feed rate of 3,880 lbs/hr, the soil in Stream 14 is:

$$3,880 * (0.00205 + 0.00107) = 12.11 \text{ lbs/hr}$$

Water. All water is driven off the soil and enters Stream 14.

PCBs. All PCBs are driven off the soil and enter Stream 14.

Organics, Nitrogen, Oxygen, and Carbon Dioxide. All organics are assumed to leave the soil and exit at Stream 14. Stream 13, infiltration air, also is a component of Stream 14. To quantify these streams, the stack test results have to be considered.

Stack flow was 21 acfm, 91°F, with a molecular weight of 30.60. This gas would have a density of (the 2.4% water in the gas is neglected):

$$(30.60 * 14.7)/(10.72 * (460 + 91)) = 0.076 \text{ lbs/ft}^3$$

At 21 acfm the hourly stack gas flow is:

$$21 * 0.076 * 60 = \mathbf{96 \text{ lbs/hr Total}}$$

This stack flow averaged 15.99, say 16%, carbon dioxide by volume. CO₂ has a molecular weight of 44 and a density of:

$$(44 * 14.7)/(10.72 * (460 + 91)) = 0.110 \text{ lbs/ft}^3$$

Thus the CO₂ flow rate is:

$$21 * 0.16 * 0.110 * 60 = \mathbf{22.2 \text{ lbs/hr CO}_2}$$

Since air is only 0.033% CO₂, this CO₂ must have come from oxidizing hydrocarbons in the soil.

The stack gas was 8.7% oxygen, or 0.087 * 21 = 1.83 acfm of oxygen with a density of:

$$(32 * 14.7)/(10.72 * (460 + 91)) = 0.076 \text{ lbs/ft}^3$$

Thus the oxygen flow rate is:

$$0.076 * 1.83 * 60 = \mathbf{8.3 \text{ lbs/hr O}_2}$$

O₂ and CO₂ were the only non-condensable gases measured in the stack flow in any quantity. This leaves 96 - 22.2 - 8.3 = 66 lbs/hr of non-condensable gas to account for. Assume that this gas is N₂, and that it enters the system as infiltration air in the RKR. Air that is trapped in the soil voids will also enter the RKR with the soil. This air entering with the soil is included in the infiltration air, Stream 13.

Air is approximately 21% oxygen and 79% nitrogen by volume, 23.4% O₂ and 76.6% N₂ by weight. The 66 lbs/hr of infiltrated N₂ would be associated with:

$$66 * (23.4/76.6) = 20.16 \text{ lbs/hr of O}_2.$$

Infiltration air would be $66 + 20.16 = 86.2$ lbs/hr. If this air were water saturated at 90°F it would carry 2.7 lbs of water. Assume that it is 74% saturated and carries 2 lbs/hr of water, for a total infiltration air rate of 88.2 lbs/hr (Stream 13).

To summarize (and round off numbers), we now know the following about the non-condensable gas flow coming out of the RKR (Stream 14):

Total flow:	96 lbs/hr	Components:	20.2 lbs/hr CO ₂
			8 lbs/hr O ₂
			66 lbs/hr N ₂

We have assumed, however, that 20 lbs/hr of oxygen enters the RKR. Oxidation of organics must be occurring that consumes $20.2 - 8 = 12.2$ lbs/hr of oxygen and produces 22 lbs/hr of CO₂. Twenty-two pounds per hour (22 lbs/hr) of CO₂ contains $22 * (32/44) = 16$ lbs/hr of O₂. Some of the oxygen must be coming from the organics in the soil. Naturally occurring organics commonly contain oxygen. Many different organic molecules are involved, and a simple equation to describe the reactions is not possible.

Assume the organic is high in oxygen, such as C₆H₆O₃. The oxidation reaction for this particular compound is:

Mol Wt:	126	32	44	18
	C ₆ H ₆ O ₃	+ 6O ₂	= 6CO ₂	+ 3H ₂ O
Moles:	0.08	0.50	0.50	0.25
Pounds:	10.50	16.00	22.00	4.50

This reaction consumes 16 lbs/hr of O₂ and produces 22 lbs/hr of CO₂, close to our required consumption of 14 lbs/hr of O₂. Note that 10.5 lb/hr of organic is destroyed.

For the material balance, the quantity of organic will be increased slightly to provide more oxygen and the following reaction will be assumed:



Note that the breech drop, Stream 12, removes 74 lbs/hr of soil containing 0.7 lb/hr of organics. This means that the organics in the RKR off-gas (Stream 14) are:

$$(38.8 - 0.7) - 12.8 = 25.3 \text{ lbs/hr}$$

Sodium Bicarbonate. The material balance is based on 1% addition of NaHCO₃ to the feed soil:

$$3,880 \text{ lbs/hr} * 0.01 = 38.8 \text{ lbs/hr of NaHCO}_3$$

At the temperatures in the reactor, the NaHCO₃ breaks down to Na₂CO₃, CO₂, and H₂O.

Deducting the 0.7 lbs/hr lost in the breech drop and assuming that 100% of the Na₂CO₃ reacts, the reaction products are:

	2NaHCO ₃	----->	Na ₂ CO ₃	+	CO ₂	+	H ₂ O
Mol Wt:	84		106		44		18
Moles:	0.45		0.23		0.23		0.22
Pounds:	38.1		24		10		4.1

Assuming that 90% of the Na₂CO₃ produced goes out in the reactor product and the other 10% leaves in the off-gas stream, each pound of NaHCO₃ produces the following flows:

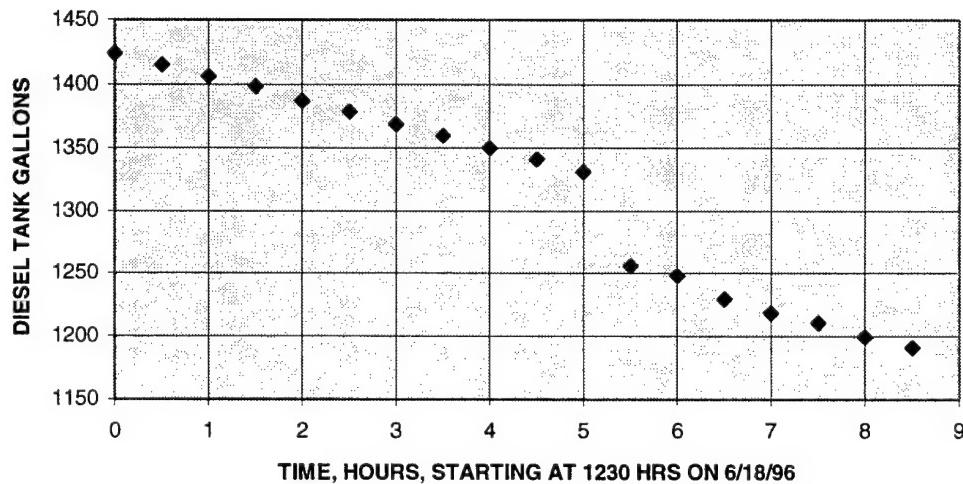
Na ₂ CO ₃	In Reactor Product	= 38.1 * 0.9 * (24/38.1) = 21.6 lbs/hr
	In Off-Gas	= 38.1 * 0.1 * (24/38.1) = 2.4 lbs/hr
CO ₂	In Off-Gas	= 38.1 * (10/38.1) = 10 lbs/hr
H ₂ O	In Off-Gas	= 38.1 * (4.1/38.1) = 4.1 lbs/hr

Stream Numbers 5 and 9 (Around Boiler)

The boiler feed water flow equals the blowdown (Stream 9) plus the steam going to the RKR and WESP (Streams 10 and 11). The blowdown, Stream 9, was not measured, and is assumed to be 10 lbs/hr.

Stream Numbers 6, 7, and 8

The gallons in the fuel oil tanks is recorded and shown on the data logs. A graph of that data is shown below.



Fuel oil is used continuously by the boiler and RKR, and is also used to fuel site equipment. Apparently the drop between 5 and 5.5 hours was caused by equipment fueling. Other than that period, the usage rate is fairly constant.

Usage rate will be determined between 0 and 5 hours and 5.5 and 8.5 hours by calculating the slope on the line in the graph.

$$0 - 5 \text{ hours: } (1424 - 1331)/(5 - 0) = 18.6 \text{ gallons per hour (GPH)}$$

$$5.5 - 8.5 \text{ hours: } (1256 - 1191)/(8.5 - 5.5) = 21.7 \text{ GPH}$$

Average fuel usage is 20.15 GPH.

The fuel split between the boiler and RKR is not measured, and will be estimated.

Steam to the RKR and WESP (Streams 10 and 11) is:

$$108 + 258 = 366 \text{ lbs/hr.}$$

Steam Generation Assumptions:

Diesel Btu/gallon = 119,000
Boiler efficiency = 0.75
Heat required to make steam = 1,100 Btu/lb

Diesel to Boiler:

366 lb/hr of steam requires: $366 * 1,100 / (.75 * 119,000) = 4.51 \text{ GPH of Diesel}$

Diesel to RKR by Difference:

$$20.15 - 4.51 = 15.6 \text{ GPH}$$

Stream Numbers 10 and 11 (Steam to RKR and WESP)

These stream flows were taken from the computer data sheets.

Stream Numbers 15 and 16 (Multicloner)

All gas leaves the multicloner in the gas stream. The solids split is given under the discussion of Stream Numbers 4, 13, and 14, ***Dry Soil***

The EPA test preliminary results show that the multicloner removes 7% of the PCBs that leave the RKR. Stream 15 contains $0.76 * 0.07 = 0.053 \text{ lbs/hr of PCB}$.

Very little data is available concerning organic removal at this point. Organics on Stream 15 are assumed to be 0.1% of the dry soil:

$$0.001 * 7.95 = 0.00795 \text{ lbs/hr}$$

Note that the non-condensable gases, O₂, CO₂, and N₂, pass through the remaining equipment to the vent stack without changing.

Stream Number 17 (WESP Off-Gas)

The WESP removes particulate, organics, and PCB from the gas stream.

PCB. The EPA test preliminary results show that the WESP removes 75% of the PCBs that leave the RKR, thus the off-gas contains:

$$0.71 - (0.76 * .75) = 0.14 \text{ lbs/hr}$$

Organics. Organic removal throughout the system was not measured, but the stack test showed that 0.26 lbs/hr of organics leave the system. Assume that half the organics are removed in the WESP and half in the Primary Condenser condensate. Twenty-five and three tenths pounds per hour (25.3 lbs/hr) of organic enter the WESP, so organics in the off-gas are:

$$25.3 - (25.3 - 0.26)/2 = 12.8$$

Dry Soil. The WESP is assumed to be 99.5% efficient, its rated value, in removing particulate, thus 0.5% of the particulate in the multiclone off-gas leaves the WESP in Stream 17.

Na₂CO₃. The Na₂CO₃ is water soluble and all is assumed to be removed in the WESP.

Water. Water in the off-gas is a function of temperature and non-condensable gas flow. The gas is assumed to be water saturated. At 210°F, the temperature recorded on the data logger, the off-gas would contain 13 lbs of water per pound of dry air. The “dry air” is the non-condensables, O₂, N₂, and CO₂, which total 106 lbs/hr. This would require an off-gas containing:

$$13 * 106 = 1,378 \text{ lbs/hr of steam}$$

The steam entering the WESP is only 258 + 576 (Stream 11 + 16) = 834 lbs/hr. This is not enough heat to generate the measured off-gas temperature. Assume a WESP outlet temperature of 205.9, which would result in 4.93 lbs water per pound of dry air, and 106 * 4.93 = 523 lbs/hr in the WESP off-gas.

Stream Numbers 22 and 23 (WESP Blowdown and Makeup Water)

WESP blowdown, Stream 22, was recorded on the data logger at 4.3 gallons per minute (gpm), making the blowdown flow $4.3 * 8.34 * 60 = 2,152$ lbs/hr of water.

Solids (and thus PCB and organics) accumulated in the WESP during operations, and the WESP was periodically shut down and cleaned out. This material balance assumes that these solids move continuously through the WESP.

WESP makeup water flow (Stream 23) is not measured and is calculated by difference:

$$23 = 17 + 22 - 16 - 11 = 523 + 2,152 - 571 - 258 = 1,845 \text{ lbs/hr}$$

(These numbers actually add to 1,846, but the material balance is done by spread sheet and small differences like this are rounding errors.)

The composition of Stream 23 is based on data from the EPA study. The stream averaged 85 ppm suspended solids and contained 5.25 ppm PCB. Using this data, the stream contains:

$$\begin{aligned} 1,841 * 85/1,000,000 &= 0.16 \text{ lbs/hr solids} \\ 1,841 * 5.25/1,000,000 &= 0.0097 \text{ lbs/hr PCB} \end{aligned}$$

The organic flow in lbs/hr in Stream 23 is assumed to be 75% of the organic flow in Stream 16. The 75% was arrived at by a trial and error calculation to make the organic flow in Streams 49 and 50 reasonable. Since the organics in these streams were not measured, the organic concentrations are assumptions.

The composition of Stream 22 is calculated by difference:

$$22 = 16 + 23 - 17$$

$$\begin{aligned} \text{PCB} &= 0.71 + 0.0097 - 0.14 = 0.58 \text{ lbs/hr} \\ \text{Dry Soil} &= 4.15 + 0.16 - 0.021 = 4.29 \text{ lbs/hr} \end{aligned}$$

Sodium carbonate is soluble and will distribute itself in the water. It is not removed by settling, filtration, or carbon treatment. See Streams 50 and 51 for the calculation of the carbonate concentration in Stream 22.

Stream Numbers 18, 19, and 21 (WESP Recycle Flows)

Stream 18 is reported on the data logger at 45 gpm. Streams 19 and 21 were never measured and the flows given were provided from the vendor. The lbs/hr of dry soil, organics, and PCB in these streams is calculated based on the fact that the concentration of these components is the same as found in the WESP blowdown, Stream 22. All these streams come off the same pipe header.

Stream Number 20 (WESP Deluge Wash)

The deluge wash is only operated to flush the WESP tubes. This occurred once every few weeks and the WESP was shut down for this operation.

Stream Numbers 24 and 25 (Primary Condenser Off-Gas and Blowdown)

The temperature of Stream 24 as recorded manually is 80°F. At this temperature, the off-gas holds 0.0023 lbs water per pound dry gas. The “dry air” is the non-condensables, O₂, N₂, and CO₂, which total 106 lbs/hr, thus the water in Stream 24 is:

$$106 * 0.023 = 2.44 \text{ lbs/hr}$$

Organics in Stream 24 are 0.26 lbs/hr, the quantity reported in the stack test at the vent stack.

Organics in Stream 25 are the difference between Streams 17 and 24:

$$12.76 - 0.26 = 12.5 \text{ lbs/hr}$$

Based on the EPA test, 15% of the PCBs in the feed soil were removed in the primary condenser condensate, Stream 25. This is:

$$0.15 * 0.761 = 0.114 \text{ lbs/hr}$$

The PCB in the off-gas is thus the difference between Streams 24 and 17:

$$0.137 - 0.114 = 0.0228 \text{ lbs/hr}$$

The small quantity of dry soil remaining is assumed to go out in the condensate, Stream 25.

Stream Numbers 26 and 27 (Primary Condenser Cooling Tower Water)

The cooling tower water flow to and from the Primary Condenser was not measured, but the vendor rated flow was 200 gpm. The inlet and outlet temperatures recorded during the June 18 test were 79°F and 90°F, respectively.

Stream Numbers 28 and 29 (Cooling Tower Makeup and Blowdown Water)

Cooling Tower makeup and blowdown water were not measured. The water had to condense about 500 lbs/hr of steam, which would require an evaporative loss of about 1 gpm. Assume a drift loss (water blown out of the tower) of 0.5 gpm and a blowdown of 1 gpm. The makeup water flow would be:

$$1 + 0.5 + 1 = 2.5 \text{ gpm}$$

Stream Numbers 30 and 31 (Chiller Condenser Cooling Tower Water)

The Cooling Tower water flow was not measured and is based on vendor supplied information.

Stream Numbers 32 and 33 (Chiller Condenser Off-Gas and Blowdown)

The chiller cools the off-gas stream down to 50°F. Air at this temperature carries 0.00903 lbs water per pound of dry air. The gas flow is 106 lbs/hr, so water in the chiller off-gas (Stream 33) is:

$$0.00903 * 106 = 0.96 \text{ lbs/hr}$$

The drain water flow (Stream 32) is the difference:

$$2.44 - 0.96 = 1.48 \text{ lbs/hr}$$

No removal of organics or PCB is assumed to occur here.

Stream Numbers 34 and 35 (HEME Off-Gas and Blowdown)

The HEME is assumed to remove all remaining PCBs. Trace PCB do pass the HEME - the stack test showed emissions to be 0.00000023 lbs/hr (0.002 pounds per year). For purposes of this material balance, all PCBs are stopped at the HEME.

Since the ambient temperature on Guam is always above 50°F, the off-gas warms between the chiller and HEME. As a result, the water content of the gas does not change going through the HEME.

Stream Numbers 36 and 37 (Carbon Inlet and Outlet)

The gas composition is assumed not to change. The carbon was for residual PCB removal and was not changed during the full-scale operations because analysis of the inlet carbon showed insignificant quantities of PCB. Some organic removal occurred at the carbon, but the carbon probably saturated with organics, ending further removal. Even when the carbon is saturated with organics, PCBs will displace the organic and attach to the carbon.

Stream Numbers 38 and 39 (Glycol To and From Chiller Condenser)

Flow was not measured and is based on vendor data. The temperatures were recorded on the vendor supplied control panel.

Stream Number 40 (Nonprocess Flows to WWTP)

This stream is for decontamination water, storm water, water from the laboratory sump, and other sources of contaminated water sent to the water treatment plant. These flows were variable, and the 50 lbs/hr is an assumption.

Stream Number 41 (WWTP Feed Wastewater)

Stream 41 is obtained by adding Streams 22, 25, 32, 34, and 40.

Stream Number 42, 43, and 44 (Flows Around Polymer Tank)

Polymer is mixed at 20 pounds of polymer per 23.5 gallons ($23.5 * 8.34 = 196$ lbs) of water.

Polymer solution addition rate is 1 ml/sec. Solution addition rate is thus:

$$1 \text{ ml/sec} * 0.0022 \text{ lbs/ml} * 60 \text{ sec/min} * 60 \text{ min/hr} = 7.92 \text{ lbs/hr}$$

$$7.92 \text{ lbs/hr} * 20 \text{ lbs polymer}/(20 + 196) = 0.73 \text{ lbs/hr polymer}$$

$$7.92 - 0.73 = 7.19 \text{ lbs/hr water}$$

Stream Number 45 (Flow to Clarifier)

This is the addition of Streams 41 and 42.

Stream Numbers 49, 50, and 51 (Flows Leaving Clarifier)

These streams must be considered together.

Stream 51 has a known flow and composition (other than sodium bicarbonate flow which was not defined in the WESP blowdown, Stream 22) that is found by adding Streams 23 and 44.

The flow rate and sodium bicarbonate level for Stream 50 can be calculated by assuming a water flow in Stream 49. This is filter cake, and the flow will be low. Assuming that the cake is 50% water, and that all the solids in Stream 45 come out in the cake (which is not the case), the flow will be the same as the solids in Stream 45, 4.31 lbs/hr.

All the water that leaves the water plant exits in Streams 37, 49, and 50. The exiting water must equal the entering water. This is expressed in the following equation for water:

$$37 + 49 + 50 = 11 + 14 + 40$$

$$50 = 11 + 14 + 40 - 37 - 49 = 258 + 571 + 50 - 0.96 - 4.31 = 874 \text{ lbs/hr}$$

The sodium carbonate is soluble and assumed to stay with the water. According to Stream 16, 0.82 lbs/hr of sodium carbonate enters the system. The small amount that leaves with the filter cake is neglected, and all the sodium carbonate is assumed to leave in Stream 50.

Since they both come out of the same tank, the composition of Stream 50 will be the same as Stream 51. Stream 51 has the same composition as Stream 23. Recall that the sodium carbonate level in Stream 23 was not specified. It can now be calculated. Stream 50 contains 0.82 pounds of sodium carbonate per 874 pounds of water. Applying this concentration to Stream 23, it contains:

$$1,845 \text{ lbs/hr water} * (0.82/874) = 1.74 \text{ lbs/hr of sodium carbonate}$$

The PCB content of Stream 23 was measured, and the organic content of this stream was assumed, so the concentration of PCB and organics in Stream 50 are calculated assuming the same concentration:

$$\begin{aligned}\text{PCB:} \quad & 874 * (0.0097/1,845) = 0.0046 \text{ lbs/hr} \\ \text{Organics:} \quad & 874 * (6.31/1,845) = 2.98 \text{ lbs/hr}\end{aligned}$$

The dry soil in Stream 49 can be calculated by difference:

$$49 = 45 - 50 - 51 = 4.31 - 0.0740 - 0.16 = 4.08 \text{ lbs/hr}$$

PCB and organics in Stream 49 are calculated by the same equation.

Stream Number 47 (Flow to Filter Press)

The clarifier sludge is assumed to be 3% solids - a typical value for sludges. The solids flow is 4.08 lbs/hr, so the water flow is $4.08/0.03 = 136$ lbs/hr. All the polymer is assumed to travel with the solids in this stream. The PCB content of Stream 47 is the same as Stream 49. The sodium carbonate is the same concentration as found in Stream 45.

Stream Number 48 (Filtrate)

The filtrate is assumed to contain no dry soil. The sodium carbonate is the same concentration as found in Stream 45.

Stream Number 52 (Flow From Bag Filter)

The bag filter is assumed to remove half the solids and half the PCBs.

Stream Number 53 (Flow From Oleophilic Media)

The oleophilic drums are assumed to remove half the remaining solids, organics, and PCBs.

Stream Number 54 (Flow from Water Carbon)

The carbon is assumed to remove all remaining solids, organics, and PCBs. The water was actually measured at 2 to 5 ppb PCB. Organics and solids were not measured.

Stream Numbers 55 and 56 (Flow Into and Out Of Treated Water Supply Tank)

This water is sprayed on the ash for cooling and dust suppression. Ash generation is 3,305 lbs/hr, and the heat capacity of coral is about 0.5 Btu/lb°F. To cool the ash down from 550°F to 100°F requires:

$$3,305 \text{ lbs/hr} * (550 - 100)^\circ\text{F} * 0.5 \text{ Btu/lb°F} = 743,625 \text{ Btu/hr}$$

To heat one pound of water from 80°F to 100°F and evaporate the water requires:

$$(100 - 80)^\circ\text{F} * 1 \text{ Btu/lb°F} + 1,000 \text{ Btu/lb} * 1 \text{ lb} = 1,020 \text{ Btu}$$

Thus to cool the ash down to 200°F requires:

$$743,625 / 1,020 = 729 \text{ lbs/hr of water}$$

To bring the soil moisture up to 10% requires:

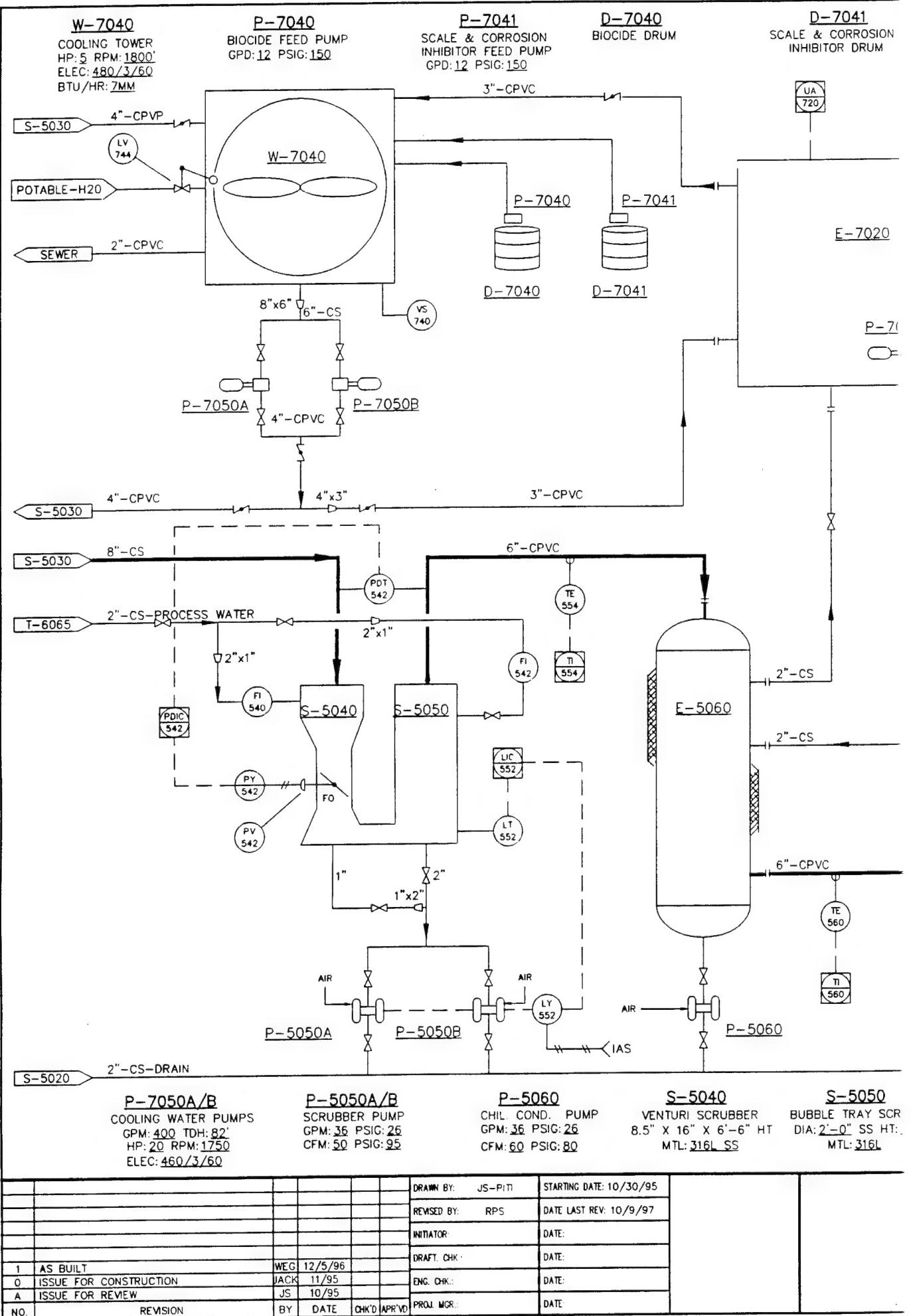
$$3,305 \text{ lbs/hr} * 0.1 = 330 \text{ lbs/hr of water}$$

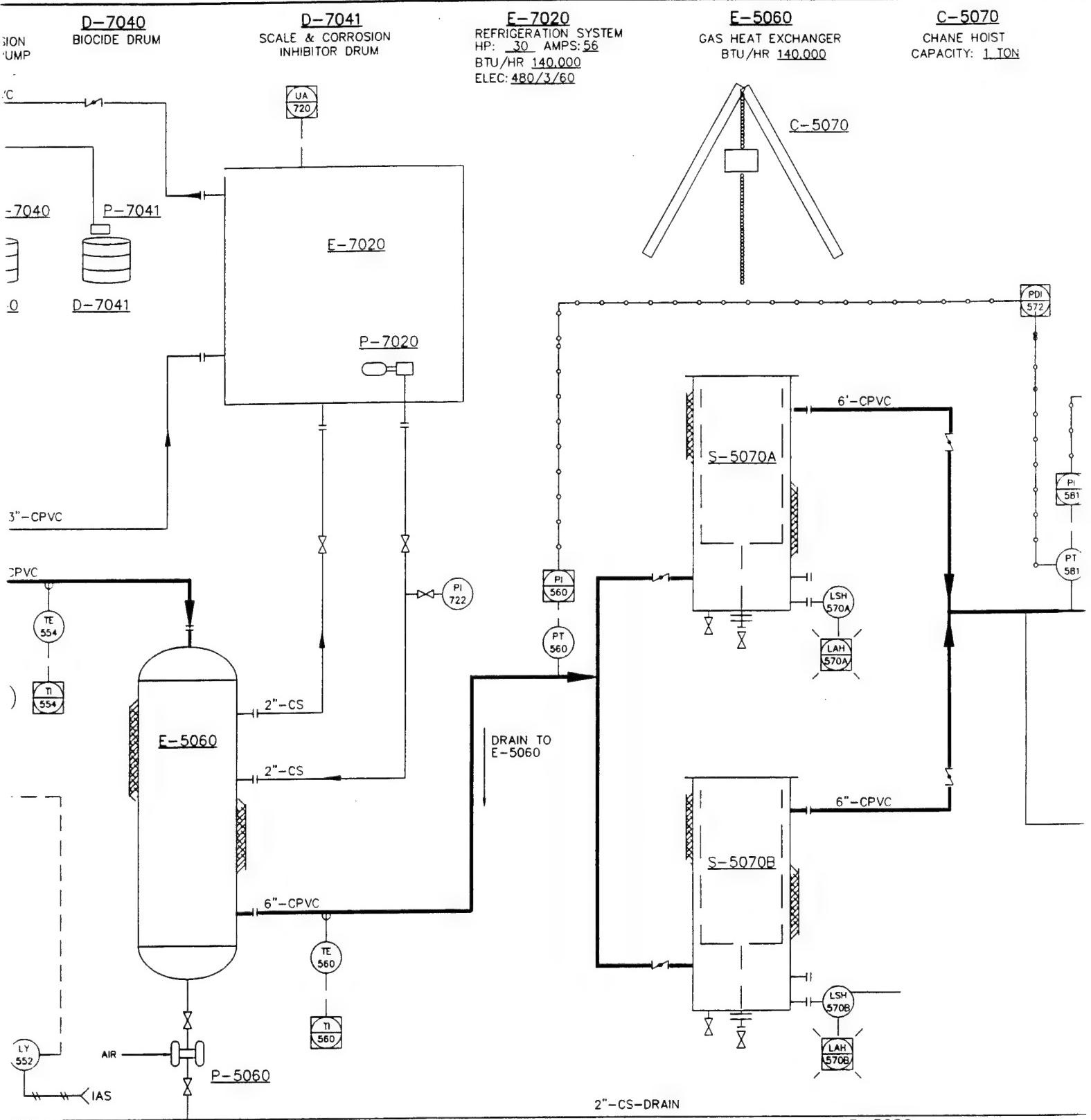
The total water usage is thus:

$$729 + 330 = 1,059 \text{ lbs/hr, or } 1,059 / (8.33 * 60) = 2.12 \text{ gpm.}$$

Excess water was used and there was a continuous runoff from the pile. Based on direct measurements, potable water addition at this point was about 5 gpm.

PIPING AND INSTRUMENTATION DIAGRAMS





060
ND. PUMP
PSIG: 26
PSIG: 80

S-5040

VENTURI SCRUBBER
8.5" X 16" X 6'-6" HT
MTL: 316L SS

S-5050

BUBBLE TRAY SCRUBBER
DIA: 2'-0" SS HT: 7'-6"
MTL: 316L

P-7020

COOLANT PUMP
HP: 5 RPM: 3500
GPM: 80 TDH110

S-5070 A/B

HIGH EFF. MIST ELIMINATOR
ELEMENT DIA: 18" HT: 6'-4"
TANK DIA: 2'-5" HT: 10'-11"
MTL: C.S.

B-5080

ID FAN
VARIABLE SPEED
HP: 20 RPM: 1800
ACFM: 200-1500
ELEC: 480/3/60

STARTING DATE: 10/30/95	
DATE LAST REV: 10/9/97	
DATE	
DATE	
DATE	
DATE	

(2)

PIPING AND INSTRUMENT
GAS CONDITIONING
NAVAL FACILITIES ENGINEER

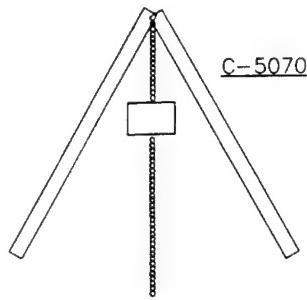
PREPARED FOR

BCDP
GUAM

-7020
RATION SYSTEM
AMPS: 56
140.000
0/3/60

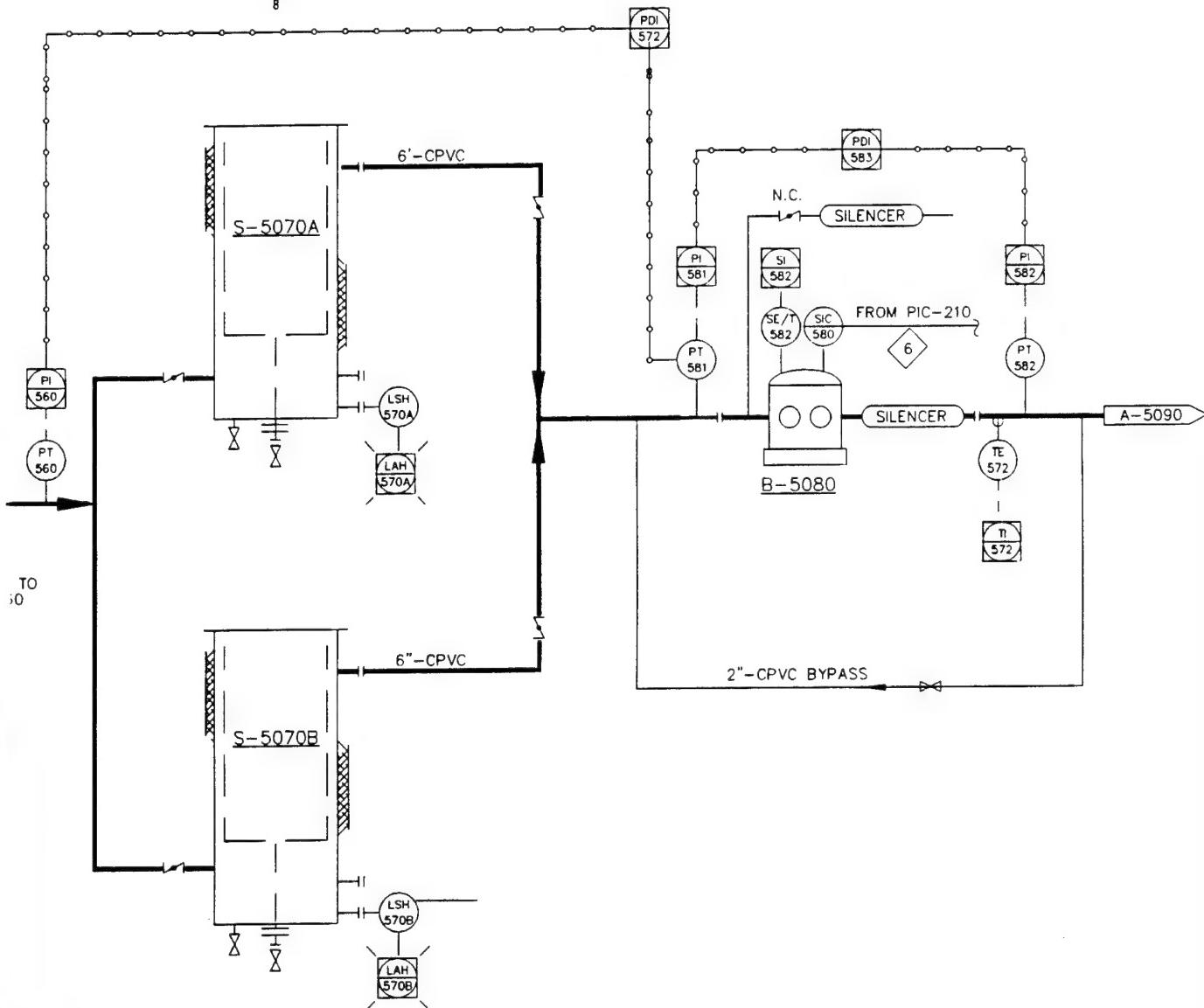
E-5060
GAS HEAT EXCHANGER
BTU/HR 140.000

C-5070
CHANE HOIST
CAPACITY: 1 TON



NOTES:

1. THE VENTURI AND IMPINJET SCRUBBERS WERE LEFT IN PLACE BUT WERE NOT USED IN THE FULL SCALE SYSTEM.
2. THE ID FAN BYPASS LOWERED THE FAN CAPACITY DURING FULL SCALE OPERATION.
3. THE ROOF MOUNTED CHANE HOIST IS USED TO CHANGE HEME ELEMENTS.



2"-CS-DRAIN

S-6040

0
PUMP
3500
+110
S-5070 A/B
HIGH EFF. MIST ELIMINATOR
ELEMENT DIA: 18" HT: 6'-4"
TANK DIA: 2'-5" HT: 10'-11"
MTL: C.S.

B-5080
ID FAN
VARIABLE SPEED
HP: 20 RPM: 1800
ACFM: 200-1500
ELEC: 480/3/60

PIPING AND INSTRUMENTATION DIAGRAM
GAS CONDITIONING - 2

NAVAL FACILITIES ENGINEERING SERVICE CENTER

PREPARED FOR

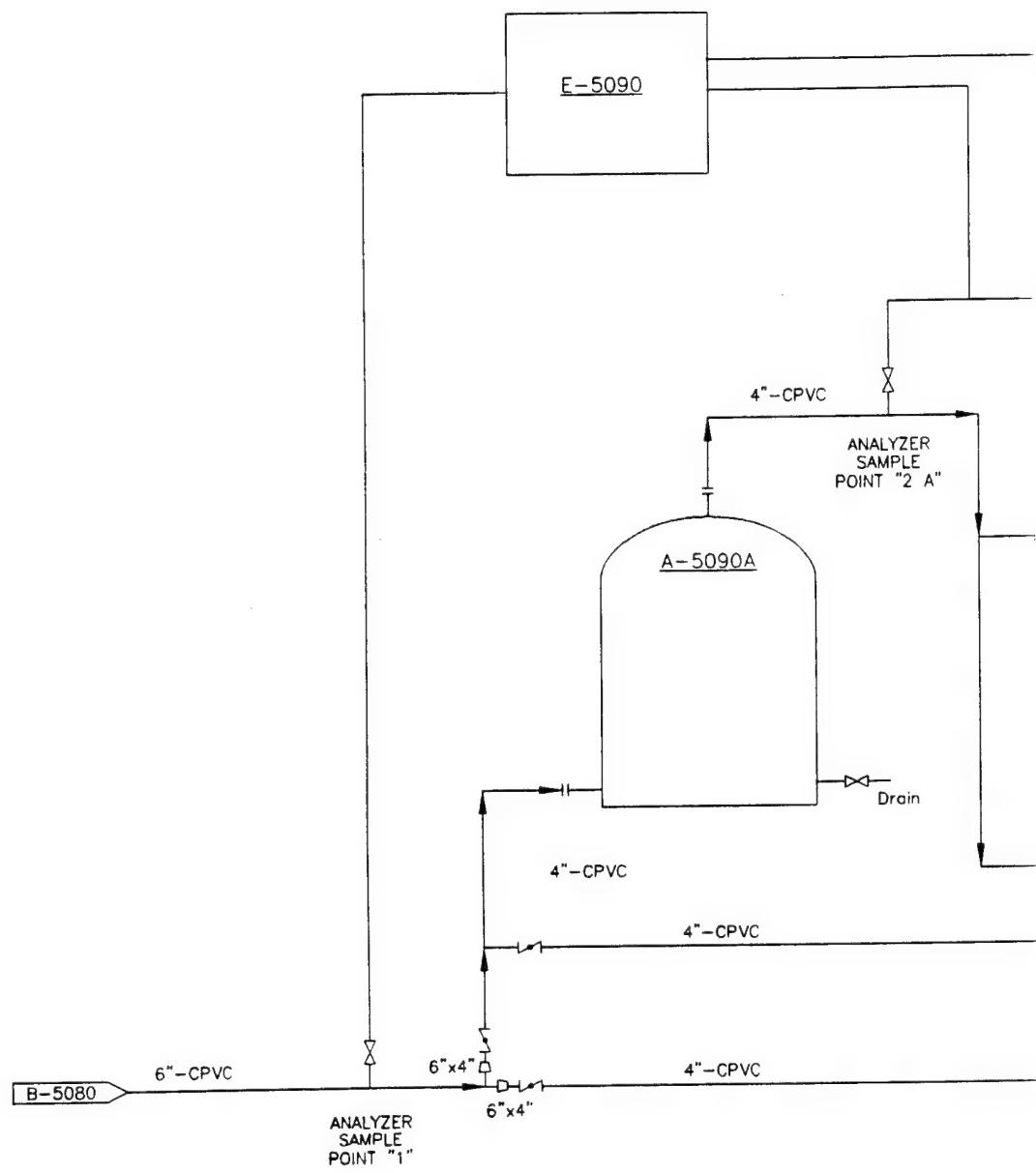
BCDP
GUAM

PROJ. NO. 767877

SHT. 3 of 6

UNIQUE
NUMBER 767877-B7

(3)



A-5090A/B

CARBON UNITS
DIA: 3'-6" HT: 7'-6"
LBS CARBON: 600

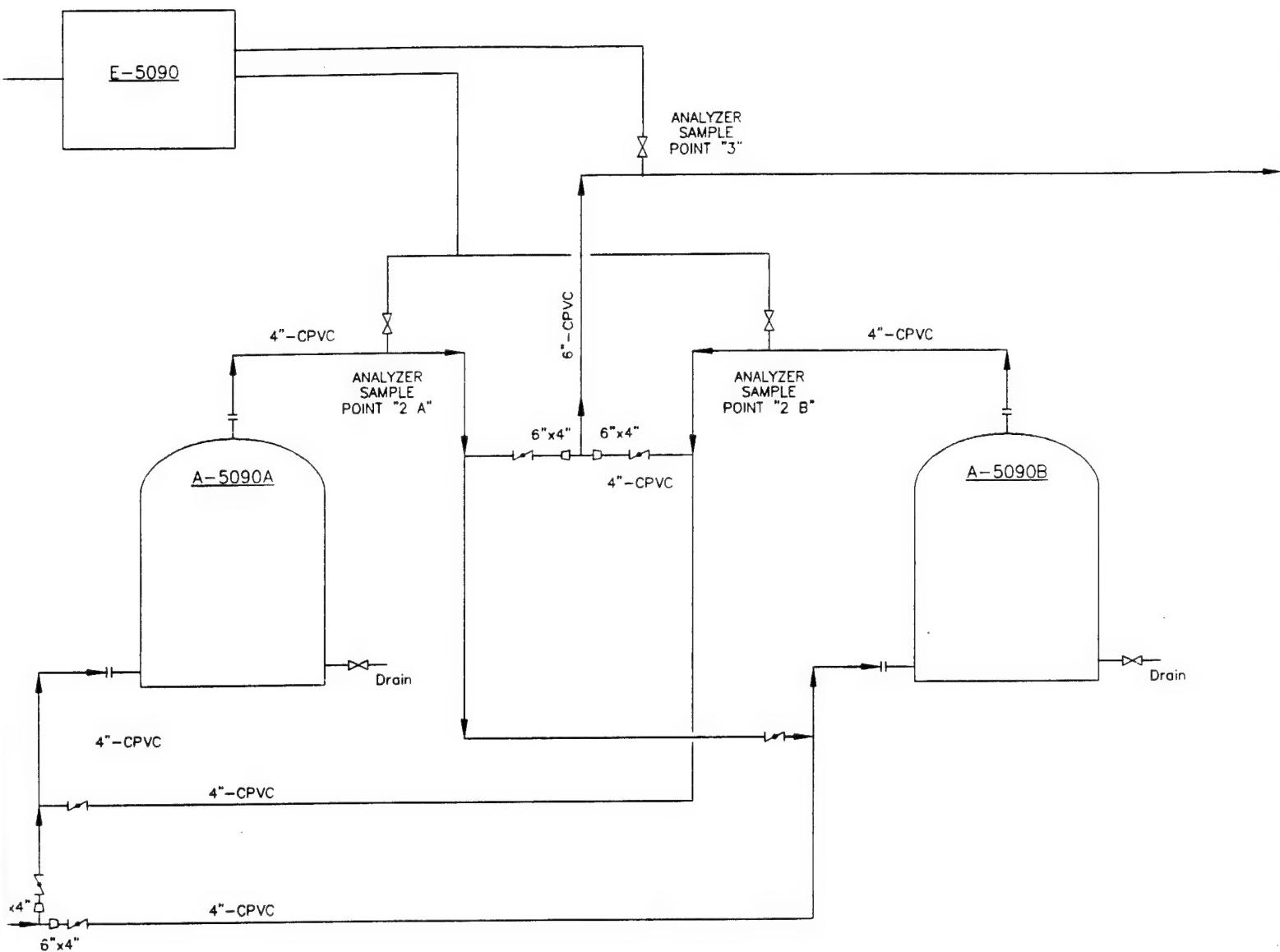
Z-5000

VENT STACK
MTL: CPVC DIA: 0'-1.5"

E-5090

CONTINUOUS EMISSIONS MONITOR

			DRAWN BY:	JS-PITI	STARTING DATE: 10/30/95		
			REVISED BY:	RPS	DATE LAST REV: 10/9/97		
			INITIATOR:		DATE:		
			DRAFT CHK.:		DATE:		
			ENG. CHK.:		DATE:		
			PROJ. MGR.:		DATE:		
1	AS BUILT	WEG 12/12/95					
0	ISSUE FOR CONSTRUCTION	JACK 11/95					
A	ISSUE FOR REVIEW	JS 10/95					
NO.	REVISION	BY	DATE	CHK'D APR'VD	PROJ. MGR.:		

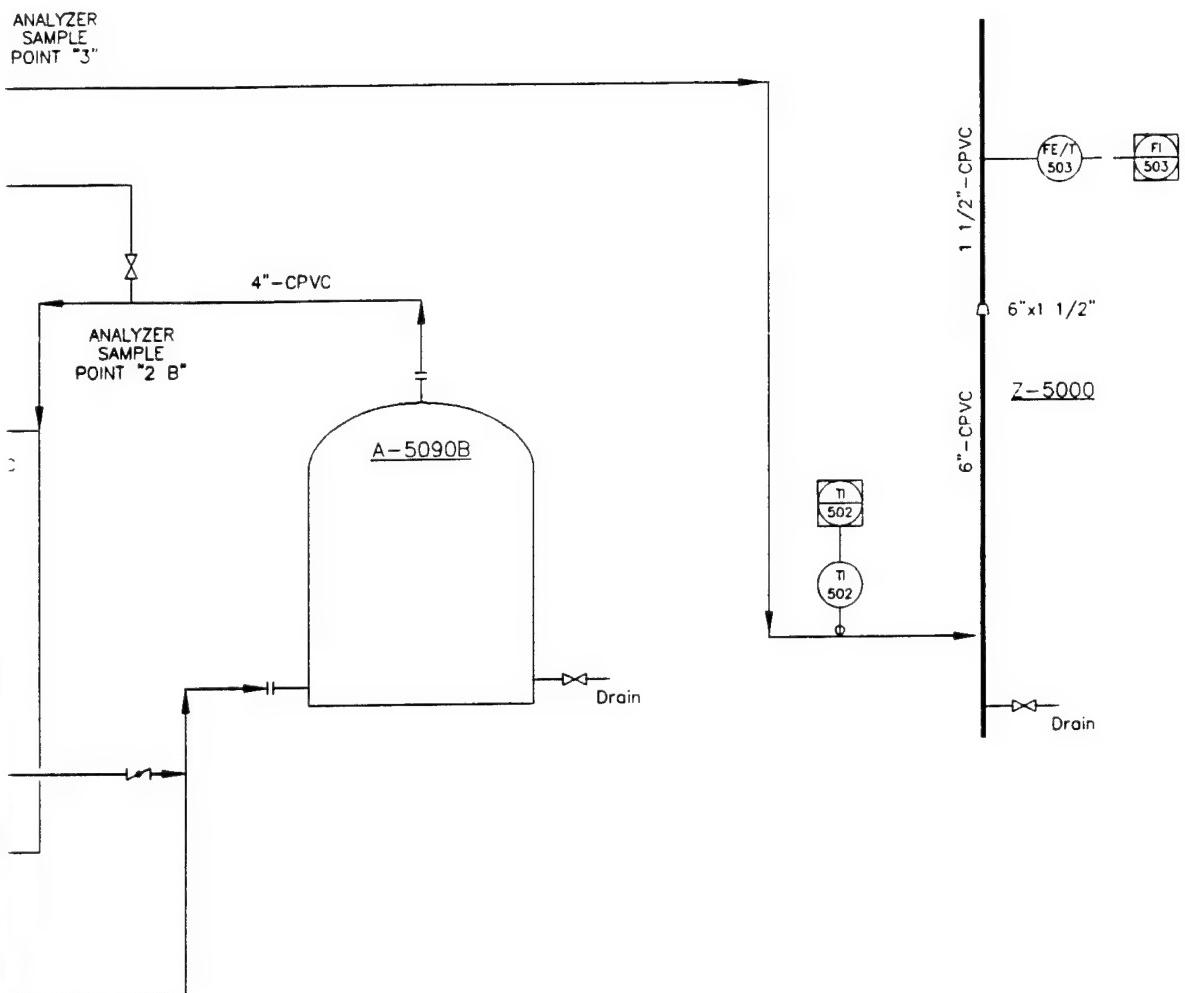


E-5090

CONTINUOUS EMISSIONS MONITOR

-1.5"

JS-PITI	STARTING DATE: 10/30/95		PIPING AND INSTRUMENTATION NAVAL FACILITIES ENGINEERING PREPARED BY:
RPS	DATE LAST REV: 10/9/97		
	DATE:		

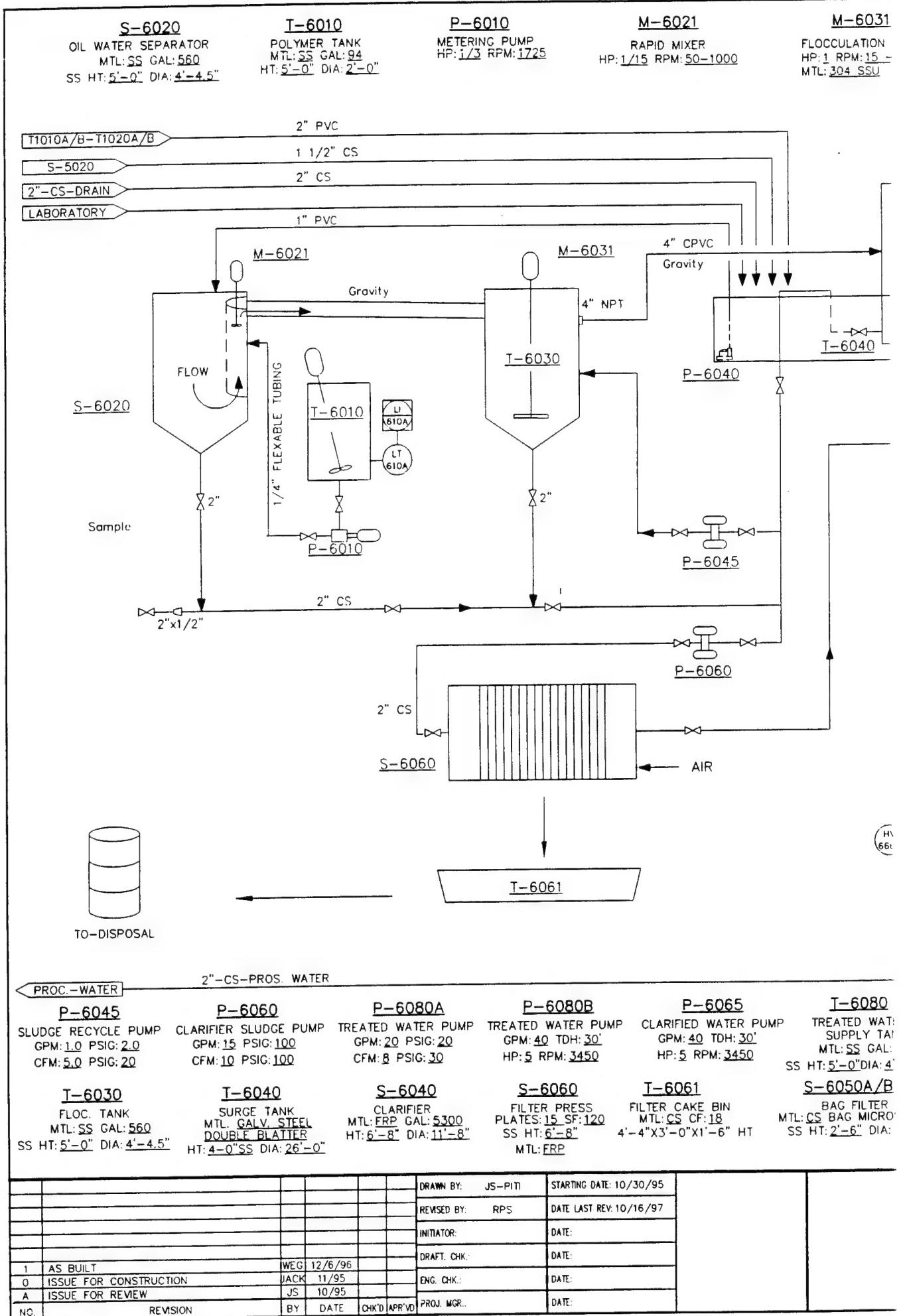


PIPING AND INSTRUMENTATION DIAGRAM
STACK
NAVAL FACILITIES ENGINEERING SERVICE CENTER
PREPARED FOR
BCDP
GUAM

PROJ. NO. 767877

SHT. 4 of 6

UNIQUE NUMBER 767877-B8



6010
ING PUMP
3 RPM: 1725

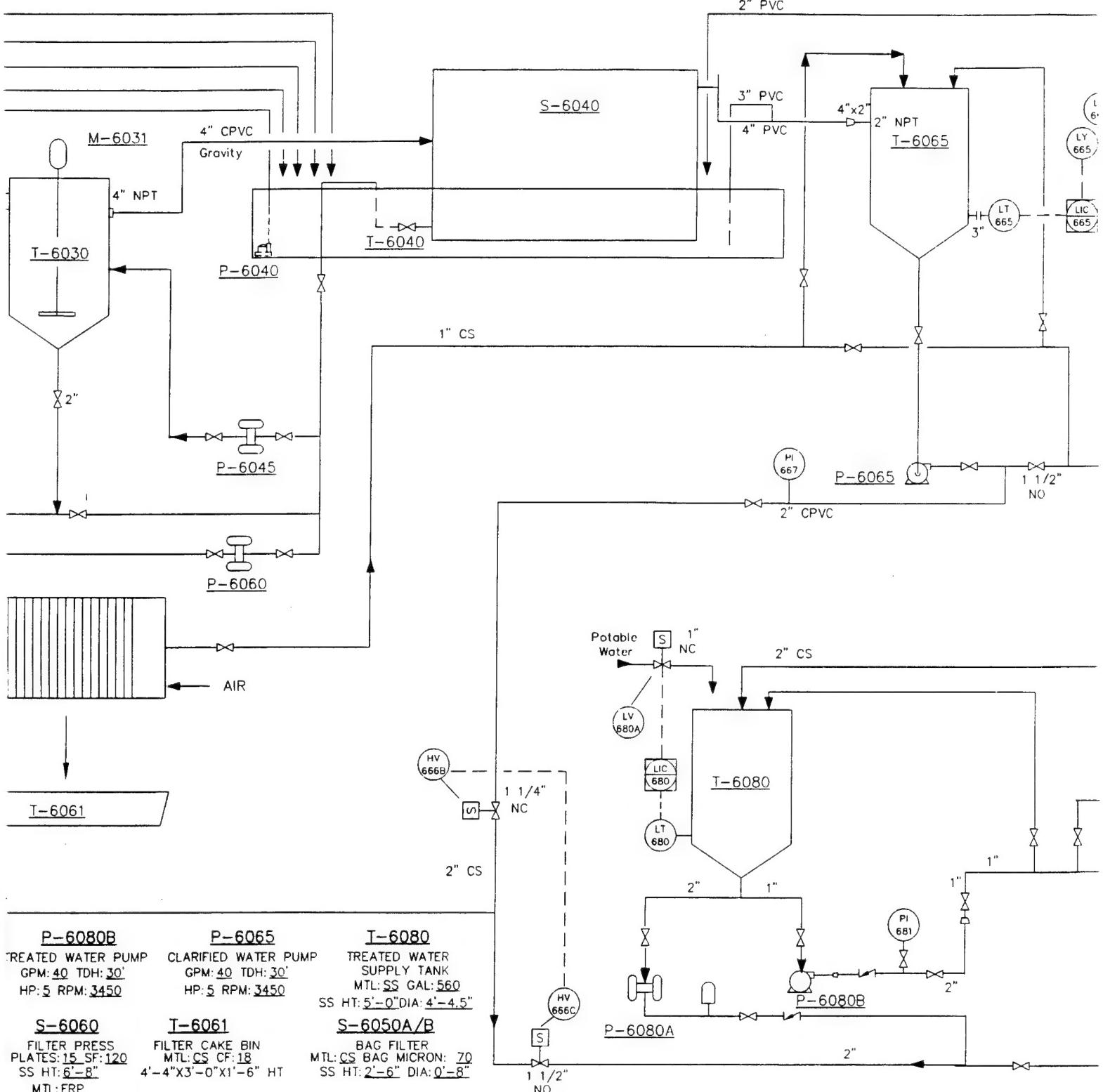
M-6021
RAPID MIXER
HP: 1/15 RPM: 50-1000

M-6031
FLOCCULATION MIXER
HP: 1 RPM: 15 - 59
MTL: 304 SSU

T-6085A/B
TREATED WATER TANK
MTL: CS GAL: 5000
20' X 5' X 8' HT

T-6065
CLARIFIED WATER TANK
MTL: SS GAL: 560
SS HT: 5'-0" DIA: 4'-4.5"

T-6070A/B
CARBON TANKS
MTL: CS GAL: 345
HT: 4'-0" DIA: 3'-10"



S-PIT	STARTING DATE: 10/30/95	
RPS	DATE LAST REV: 10/16/97	
	DATE:	

PIPING AND INSTRUMENTATION
WATER
NAVAL FACILITIES ENGINEERING

PREP
BG

(2)

T-6085A/B

T-6065

TREATED WATER TANK
MTL: CS GAL: 5000
20' X 5' X 8' HT

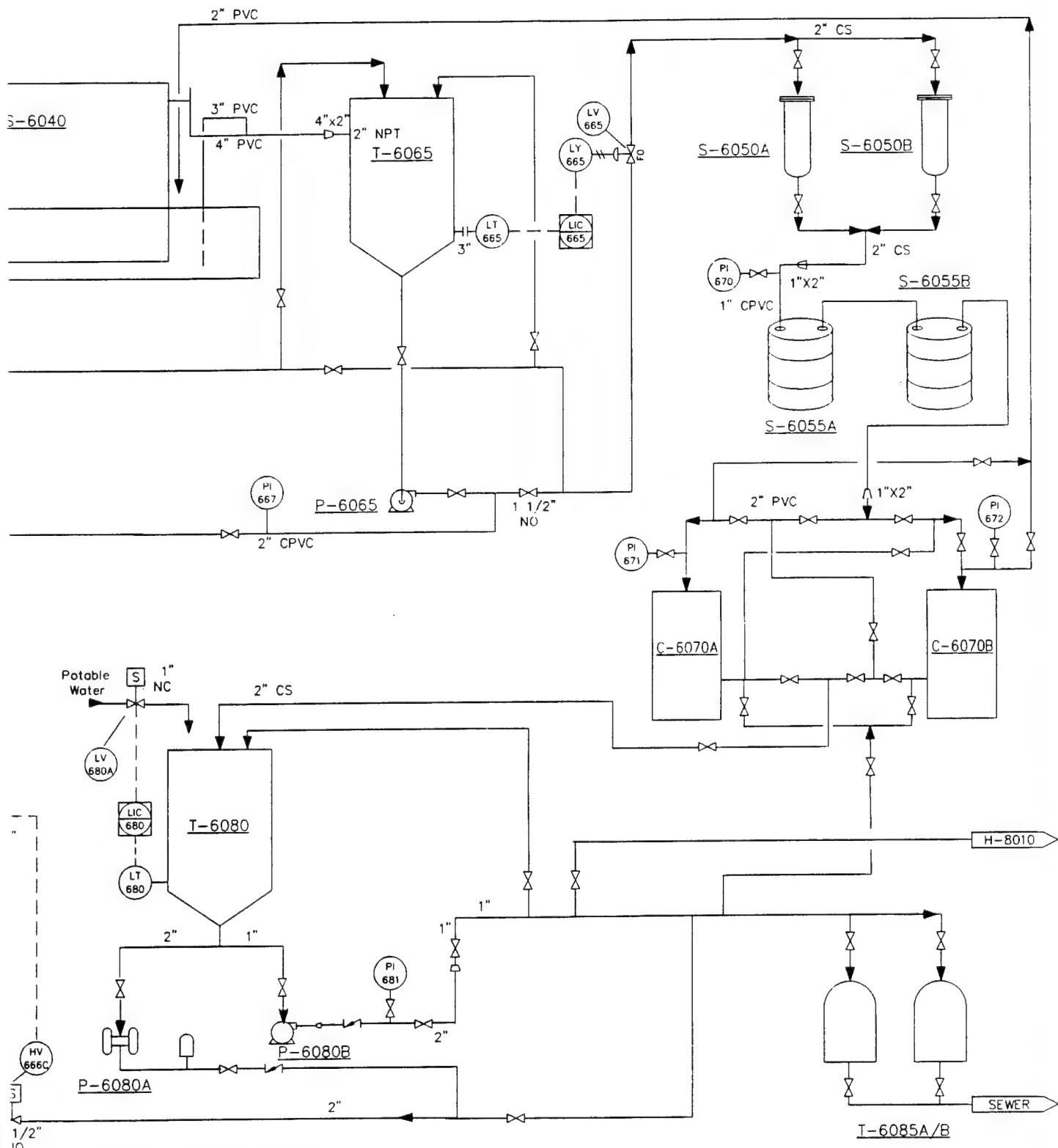
CLARIFIED WATER TANK
MTL: SS GAL: 560
SS HT: 5'-0" DIA 4'-4.5"

T-6070A/B

CARBON TANKS
MTL: CS GAL: 345
HT: 4'-0" DIA: 3'-10"

S-6055A/B

OLEOPHILIC CLAY DRUM
MTL:CS GAL:55
DIA: 1'-11.5" HT: 2'-11.5"



PIPING AND INSTRUMENTATION DIAGRAM
WATER TREATMENT
NAVAL FACILITIES ENGINEERING SERVICE CENTER
PREPARED FOR

PROJ. NO. 767877

SHT. 5 of 6

UNIQUE
NUMBER 767877-B9

INSTRUMENT ABBREVIATIONS

AE	ACID ELEMENT (pH PROBE)
AI	ACID (pH) INDICATOR
AIC	ACID (pH) INDICATOR CONTROL
AT	ACID TOTALIZER
FAL	FLOW ALARM LOW
FALL	FLOW ALARM LOW LOW
FC	FAIL CLOSED
FE/T	FLOW ELEMENT TRANSMITTER
FE	FLOW ELEMENT
FI	FLOW INDICATOR
FIC	FLOW INDICATOR CONTROLLER
FO	FAIL OPEN
FT	FLOW TRANSMITTER
FV	FLOW CONTROL VALVE
FY	AUTOMATIC FLOW CONTROL
HS	HAND SWITCH
HV	HAND VALVE
LAH	LEVEL ALARM HIGH
LAHL	LEVEL ALARM HIGH LOW
LI	LEVEL INDICATOR
LIC	LEVEL INDICATOR CONTROLLER
LS	LEVEL SWITCH
LSH	LEVEL SWITCH HIGH
LSHL	LEVEL SWITCH HIGH/LOW
LSL	LEVEL SWITCH LOW
LT	LEVEL TRANSMITTER
LV	LEVEL VALVE
NC	NORMALLY CLOSED
NO	NORMALLY OPEN
PAL	PRESSURE ALARM LOW
PDI	PRESSURE DIFFERENTIAL INDICATOR
PDIC	PRESSURE DIFFERENTIAL INDICATOR CONTROLLER
PDT	PRESSURE DIFFERENTIAL TRANSMITTER
PI	PRESSURE INDICATOR
PIC	PRESSURE INDICATOR CONTROLLER
PSH	PRESSURE SWITCH HIGH
PSL	PRESSURE SWITCH LOW
PT	PRESSURE TRANSMITTER
SC	SPEED CONTROLLER
SE/T	SPEED ELEMENT TRANSMITTER
SE	SPEED ELEMENT
SI	SPEED INDICATOR
SIC	SPEED INDICATOR CONTROLLER
SS	SPEED SWITCH
TAL	TEMPERATURE ALARM LOW
TC	TEMPERATURE CONTROLLER
TE	TEMPERATURE ELEMENT
TI	TEMPERATURE INDICATOR
TIC	TEMPERATURE INDICATOR CONTROLLER
TT	TEMPERATURE TRANSMITTER
UA	UNIT ALARM
VS	VIBRATION SWITCH
WIC	WEIGHT INDICATOR CONTROLLER
WIT	WEIGHT INDICATOR TOTALIZER
ZA	VALVE INTERLOCK ALARM
ZS	VALVE STATUS (OPENED OR CLOSED)

OTHER ABBREVIATIONS

AAC	AMPS ALTERNATING CURRENT
BTU	BRITISH THERMAL UNIT
CF	CUBIC FEET
CFM	CUBIC FEET PER MINUTE
CPVC	CHLORINATED POLYVINYL CHLORIDE
DIA	DIAMETER
ELEC	ELECTRIC
FRP	FIBERGLASS REINFORCED PLASTIC
FT	FOOT
GAL	GALLON
GPD	GALLONS PER DAY
GPH	GALLONS PER HOUR
HP	HORSE POWER
HR	HOUR
HT	HEIGHT
KVA	KILOVOLT AMPS
KVDC	KILOVOLTS DIRECT CURRENT
LB	POUND
mADC	MILLIAMPS DIRECT CURRENT
MTL	MATERIAL
NPT	NORMAL PIPE THREAD
PSIG	POUNDS PER SQUARE INCH GAGE
PVC	POLYVINYL CHLORIDE
RPM	REVOLUTIONS PER MINUTE
SCFM	STANDARD CUBIC FEET PER MINUTE
SEC	SECOND
SF	SQUARE FEET
SS	STAINLESS STEEL
SS HT	STRAIGHT SIDE HEIGHT
TDH	TOTAL DYNAMIC HEAD
VAC	VOLTS ALTERNATING CURRENT
VIB	BIN VIBRATOR

INSTRUMENT SYMBOLS



LOCALLY MOUNTED INSTRUMENT



PANEL MOUNTED INSTRUMENT



COMPUTER READ OUT



COMPUTER READ OUT AND ALARM



ALARM AND CONTROL FEATURE

					DRAWN BY: JS-PITI	STARTING DATE: 10/30/95	
					REVISED BY: RPS	DATE LAST REV: 10/16/97	
					INITIATOR:	DATE:	
					DRAFT. CHK.:	DATE:	
					ENG. CHK.:	DATE:	
					PROJ. MGR.:	DATE:	
1 AS BUILT	WEG	B/97					
A1 ISSUE FOR REVIEW - 2	JACK	11/95					
A ISSUE FOR REVIEW	JS	10/95					
NO.	REVISION	BY	DATE	CHK'D APR'VD			

(1)

OTHER ABBREVIATIONS

AAC	AMPS ALTERNATING CURRENT
BTU	BRITISH THERMAL UNIT
CF	CUBIC FEET
CFM	CUBIC FEET PER MINUTE
CPVC	CHLORINATED POLYVINYL CHLORIDE
DIA	DIAMETER
ELEC	ELECTRIC
FRP	FIBERGLASS REINFORCED PLASTIC
FT	FOOT
GAL	GALLON
GPD	GALLONS PER DAY
GPH	GALLONS PER HOUR
HP	HORSE POWER
HR	HOUR
HT	HEIGHT
KVA	KILOVOLT AMPS
KVDC	KILOVOLTS DIRECT CURRENT
LB	POUND
mADC	MILLIAMPS DIRECT CURRENT
MTL	MATERIAL
NPT	NORMAL PIPE THREAD
PSIG	POUNDS PER SQUARE INCH GAGE
PVC	POLYVINYL CHLORIDE
RPM	REVOLUTIONS PER MINUTE
SCFM	STANDARD CUBIC FEET PER MINUTE
SEC	SECOND
SF	SQUARE FEET
SS	STAINLESS STEEL
SS HT	STRAIGHT SIDE HEIGHT
TDH	TOTAL DYNAMIC HEAD
VAC	VOLTS ALTERNATING CURRENT
VB	BIN VIBERATOR

ROLLER

PROCESS SYMBOLS

	BUTTERFLY VALVE
	CHECK VALVE
	FLOAT CONTROLLED VALVE
	SOLENOID VALVE
	CONTROL VALVE
	Y STRAINER
	CENTRIFUGAL PUMP
	DIAPHRAGM PUMP
	STEAM TRAP
	FLANGE
	VESSEL INSULATION
	ROTARY LOBE BLOWER
	PIPE INSULATION
	PROGRESSING CAVITY PUMP
	PIPE REDUCER
	FLOAT CONTROLLED SUMP PUMP
	ACCUMULATOR

INSTRUMENT SYMBOLS

	LOCALLY MOUNTED INSTRUMENT
	PANEL MOUNTED INSTRUMENT
	COMPUTER READ OUT
	COMPUTER READ OUT AND ALARMED
	ALARM AND CONTROL FEATURE

CONTROL SYSTEMS INTERLOC

- ① R-2010 BURNERS SHUT DOWN IF SHELL
- ② FEED BELT (H-1010) IS SHUT DOWN AT
- ③ WESP POWER SHUTS DOWN IF BOTH VALVE FEED BELT (H-1010) SHUTS DOWN IF BOTH
- ④ TI 524 CONTROLS FV 714 TO MAINTAIN A
TI 524 ALARMS AT LOW TEMPERATURE
TI 524 SHUTS OFF POWER TO THE WESP
- ⑤ FI521 ALARMS AT LOW FLOW.
FI521 SHUTS OFF POWER TO THE WESP
- ⑥ SIC 580 VARIES FAN SPEED TO MAINTAIN

DRAWN BY:	JS-PITI	STARTING DATE: 10/30/95		PIPING SY NAVAL FACI
REVISED BY:	RPS	DATE LAST REV: 10/16/97		
INITIATOR:		DATE:		
DRAFT. CHK.:		DATE:		
ENG. CHK.:		DATE:		
PROJ. MGR.:		DATE:		

PROCESS SYMBOLS

✓	BUTTERFLY VALVE
↗	CHECK VALVE
↙	FLOAT CONTROLLED VALVE
☒	SOLENOID VALVE
☒	CONTROL VALVE
↖	Y STRAINER
○	CENTRIFUGAL PUMP
H	DIAPHRAGM PUMP
L	STEAM TRAP
— —	FLANGE
■	VESSEL INSULATION
■	ROTARY LOBE BLOWER
—□—	PIPE INSULATION
~~~~~	PROGRESSING CAVITY PUMP
□	PIPE REDUCER
↓	FLOAT CONTROLLED SUMP PUMP
●	ACCUMULATOR

## CONTROL SYSTEMS INTERLOCKS

- ① R-2010 BURNERS SHUT DOWN IF SHELL ROTATION STOPS
- ② FEED BELT (H-1010) IS SHUT DOWN AT HIGH HOPPER LEVEL
- ③ WESP POWER SHUTS DOWN IF BOTH VALVES OPEN AT THE SAME TIME  
FEED BELT (H-1010) SHUTS DOWN IF BOTH VALVES OPEN AT THE SAME TIME
- ④ TI 524 CONTROLS FV 714 TO MAINTAIN A SET POINT TEMPERATURE IN THE WESP GAS OUTLET.  
TI 524 ALARMS AT LOW TEMPERATURE  
TI 524 SHUTS OFF POWER TO THE WESP AT LOW LOW TEMPERATURE.
- ⑤ FI521 ALARMS AT LOW FLOW.  
FI521 SHUTS OFF POWER TO THE WESP AT LOW LOW FLOW.
- ⑥ SIC 580 VARIES FAN SPEED TO MAINTAIN THE PRESET VACCUUM IN R-2010.

PIPING AND INSTRUMENTATION DIAGRAM  
SYMBOLS AND ABBREVIATIONS  
NAVAL FACILITIES ENGINEERING SERVICE CENTER  
PREPARED FOR  
BCDP  
GUAM

PROJ. NO. 767877

SHT. 6 of 6

UNIQUE NUMBER 767877-B10

**APPENDIX B**

**RAPID START PLANT OPERATING DATA**

## **RAPID START PLANT OPERATING DATA**

The computer data logger had not yet been installed when the rapid start run occurred. Operating data were hand logged hourly while the plant operated.

The log sheets in this appendix cover the period of the rapid start stack test, from July 14 through 22. There are no bed temperature reading until July 22 because the instrument failed and could not be repaired until the 22nd. The HEME D/P and Scrubber D/P data shown on the attached sheets were calculated. The HEME D/P is the difference between the HEME inlet and Fan inlet. The Scrubber D/P is the difference between the Scrubber inlet and the HEME inlet.

The "Gas % Open" column applies to the sweep gas valve. Sweep gas came through a butterfly valve on the soil discharge end of the kiln. The valve could be set from "0" to "100" percent open, and this column records the valve setting.

## Rapid Start Plant Operating Data

Day	Time	Zone				Bed				Temperature, Degrees F				Cyclone Exit	Scrubber Inlet	Scrubber Outlet	ID Fan Outlet
		1	2	3	4	1	2	3	4	5	4	5	5				
14-Jul	01:00	1070	1033	1000	1094					315	196	198	187	120			
14-Jul	02:00	1145	1150	1027	1105					359	227	229	108	108			
14-Jul	03:00	1081	1079	1087	1106					359	227	234	108	108			
14-Jul	04:00	1068	1070	1073	1109					346	229	232	108	109			
14-Jul	05:00	1070	1080	1089	1109					239	248	231	113	112			
14-Jul	06:00	1069	1102	1070	1080					374	249	254	167	112			
14-Jul	07:00	1071	1101	1072	1081												
14-Jul	08:00	1065	1096	1079	1083					369	242	253	112	113			
14-Jul	09:00	1066	1105	1086	1085					373	236	254	112	114			
14-Jul	10:00	1074	1098	1082	1083					377	229	249	113	114			
14-Jul	11:00	1065	1094	1092	1086					353	220	246	112	115			
14-Jul	12:00	1080	1099	1096	1086					366	238	257	114	119			
14-Jul	13:00	1073	1101	1095	1077					379	250	270	116	120			
14-Jul	14:00	1077	1099	1091	1082					378	251	271	122	125			
14-Jul	15:00	1070	1100	1082	1080					392	254	275	119	122			
14-Jul	16:00	1063	1095	1076	1085					364	245	264	122	125			
14-Jul	17:00	1070	1100	1070	1088												
14-Jul	21:00	1063	1082	1073	1054					366	235	242	116	113			
14-Jul	22:00	1060	1085	1073	1060					357	227	238	117	115			
14-Jul	23:00	1073	1040	1030	1117					321	212	222	120	119			
14-Jul	24:00	1072	1077	1136	1036					308	133	185	113	109			
15-Jul	02:00	1073	1101	1108	1081					426	246	260	111	113			
15-Jul	03:00	1071	1097	1067	1079					399.2	250.9	254.8	111	114.2			
15-Jul	04:00	1067	1097	1069	1081					392.1	253.3	254.3	111.5	114.2			
15-Jul	05:00	1069	1100	1049	1078					390.4	252.2	255.1	112.6	115.6			
15-Jul	06:00	1074	1104	1088	1098					344.9	230	231	113.5	113.5			
15-Jul	07:00	1102	1080	1105	1095					337	230	231	114	113			
15-Jul	08:00	1116	1095	1109	1094					347	231	234	113	113			
15-Jul	09:00	1094	1101	1062	1112					337	217	230	113	113			
15-Jul	10:00	1094	1093	1050	1102					330	212	219	112	112			
15-Jul	11:00	1071	1074	1033	1086					331	175	196	112	110			
15-Jul	12:00	1065	1054	1038	1091					223.6	215.1	209	116	140.9			
15-Jul	13:00	1090	1096	1097	1110					312.6	220.8	220.2	115.5	116.4			
15-Jul	14:00	1103	1107	1095	1106					322.1	203	214	113.4	116.5			
15-Jul	15:00	1070	1101	1070	1080					334.4	206.9	197.5	112.2	115.6			

### Rapid Start Plant Operating Data

Day	Time	Pressure, Inches of Water										Stack ACFM	Gas % Open
		Kiln Kiln Feed	Tons/Hr Ash	Cyclone D/P	Scrubber Inlet	HEME Inlet	Fan Inlet	HEME D/P	Fan Outlet	Scrubber D/P	Fan RPM		
14-Jul	01:00	113	504	0.74	0.5	1.5	2	14	18.6	10.1	4.6	12	1080
14-Jul	02:00	106	567	1.17	0.42	1.5	2	15	22.4	9.9	7.4	13	1030
14-Jul	03:00	106	569	0.8	0.48	1.5	3	15	21.9	10	6.9	12	1060
14-Jul	04:00	106	554	0.69	0.38	1	3	16	19.2	9.8	3.2	13	1030
14-Jul	05:00	107	535	0.8	0.5	1.5	2	12	18.5	9	6.5	10	980
14-Jul	06:00	117	486	0.75	0.57	2	3.5	16	20.3	8.2	4.3	12.5	940
14-Jul	07:00						3.5			0	-3.5		70
14-Jul	08:00	111	528	0.71	0.51	2	3.5	17	21.8	9.2	4.8	13.5	910
14-Jul	09:00	115	508	0.78	0.53	2	3.5	14	19	8.8	5	10.5	880
14-Jul	10:00	113	505	0.77	0.63	2		15	18	8.7	3	15	940
14-Jul	11:00	115	515	0.87	0.51	2	3.5	15	17	5.5	2	11.5	830
14-Jul	12:00	114	507	0.75	0.35	3	3.5	29	37	15.3	8	25.5	1530
14-Jul	13:00	120	490	0.82	0.5	3	1	19	28	13.6	9	18	1410
14-Jul	14:00	121	487	0.82	0.45	3	0.5	18	26.8	13.5	8.8	17.5	1410
14-Jul	15:00	120	568	0.73	0.54	3	0.5	18	26.3	13.8	8.3	17.5	1410
14-Jul	16:00	122	512	0.76	0.45	2.5	0.5	17.5	26.9	13.7	9.4	17	1410
14-Jul	17:00						0.5			0	-0.5		487
14-Jul	21:00	108	326	0.79	0.46	2		10	13.4	5.5	3.4	10	790
14-Jul	22:00	111	458	0.96	0.5	1	2	10	13.1	5.5	3.1	8	790
14-Jul	23:00	117	558	0.96	0.65	1		10	12.2	5.6	2.2	10	790
14-Jul	24:00	109	503	0.84	0.53	1	2	10	16	9.8	6	8	970
15-Jul	02:00	105	474	0.69	0.47	1.5	2	9.5	15.5	19.7	6	7.5	850
15-Jul	03:00	108.8	515.3	0.65	0.43	1.5	2	13	20.7	26	7.7	11	1000
15-Jul	04:00	108.9	534.8	0.65	0.48	1.5	2	13	17.3	26.1	4.3	11	940
15-Jul	05:00	109.9	514.6	0.65		1.5	2	14	24.7	26.3	10.7	12	468
15-Jul	06:00	110	550	0.77	0.55	1.75	1.5	14	17.3	10	3.3	12.5	890
15-Jul	07:00	110	547	0.77	0.63	1.5	1.5	13	17.6	9.8	4.6	11.5	920
15-Jul	08:00	111	526	0.73	0.74	1.5	1.5	10	17.4	9.8	7.4	8.5	1080
15-Jul	09:00	111	535	0.64	0.59	1.5	1.5	12	16.5	9.1	4.5	10.5	940
15-Jul	10:00	110	568	0.6	0.4	1.5	1.5	13	16.2	9.4	3.2	11.5	960
15-Jul	11:00	105	461	0.73	0.7	1.5	1.5	12	18	10	6	10.5	820
15-Jul	12:00	111.3	449.9	0.64	0.47	1.5	1.5	14	18	9.6	4	12.5	1040
15-Jul	13:00	113.5	475.1	0.85	0.62	1.5	1.5	13	18.9	9.8	5.9	11.5	1050
15-Jul	14:00	112.7	501.8	0.64	0.63	1.5	1.5	11	18.1	26.1	7.1	9.5	970
15-Jul	15:00	111.7	497.2	0.79	0.63	1.5	1.5	13	19.8	26	6.8	11.5	920

## Rapid Start Plant Operating Data

Day	Time	Zone				Bed				Temperature, Degrees F				ID Fan Outlet	
		1	2	3	4	1	2	3	4	5	Bed	Kiln Exit	Cyclone Exit	Scrubber Inlet	Scrubber Outlet
15-Jul	16:00	1097	1090	1099	1086						328.7	214.5	194.2	115.5	117.5
15-Jul	17:00	1082	1082	1083	1102						327.3	153.9	190.7	112.4	114
15-Jul	18:00	1129	1079	1062	1047						317.5	154.4	184.7	111.8	113.5
15-Jul	22:00	1027	1083	1105	1103						375	218	233	112	114
15-Jul	23:00	1071	1099	1109	1098						376.5	211.9	235.4	113.4	114.6
15-Jul	24:00	1076	1095	1073	1880						365.9	208.4	232.7	114.3	116.1
16-Jul	01:00	1088	1106	1070	1075						389	239	246	118	120
16-Jul	02:00	1080	1100	1007	1076						413	242	249	114	120
16-Jul	03:00	1068	1100	1071	1083						375	223	222	119	115
16-Jul	04:00	1065	1090	1069	1076						359	221	219	120	118
16-Jul	05:00	1067	1096	1068	1080						359	211	217	120	118
16-Jul	06:00	1071	1103	1069	1074						367	242	268	113	116
16-Jul	07:00	1065	1067	1064	1064						358	243	245	115	118
16-Jul	08:00										407	234	244	102	119
16-Jul	09:00	1092	1097	1072	1080						432	238	259	118	118
16-Jul	10:00	1070	1098	1072	1078						403	226	252	113	122
16-Jul	11:00	1089	1071	1064	1085						351	216	234	119	122.8
16-Jul	12:00	1096	1079	1069	1099						354	207	230	125	121
16-Jul	13:00	1097	1114	1086	1112						372	210	233	115	122
16-Jul	14:00	1104	1048	1045	1116						360	213	231	121	124
16-Jul	15:00	1101	1092	1080	1099						335	208	225	127	125
16-Jul	16:00	1097	1061	1060	1102						335.5	208	224	123	126
16-Jul	17:00	1105	1053	1064	1104						348.5	206	225	120	124
16-Jul	18:00	1099	1081	1070	1105						366	212	231	117	121
16-Jul	19:00	1070	1102	1065	1080						365	216	235	119	121
16-Jul	20:00	1070	1103	1069	1084						373	222	240	118	121
16-Jul	21:00	1087	1115	1080	1085						405	262	276	118	123
16-Jul	22:00	1060	1080	1069	1079						384	224	278	116	121
16-Jul	23:00	1068	1104	1075	1083						381	235	244	119	121
16-Jul	24:00	1069	1107	1075	1082						377	381	241	116	119
17-Jul	01:00	1064	1094	1061	1072						328	207	212	122	122
17-Jul	02:00	1053	1103	1073	1076						326	204	208	123	112
17-Jul	03:00	1071	1100	1070	1085						328	203	205	123	120
17-Jul	04:00	1073	1102	1070	1073						331	201	204	123	120
17-Jul	05:00	1066	1099	1073	1079						326	184	197	121	118
17-Jul	06:00	1072	1105	1077	1080						355	217	203	120	118

Rapid Start Plant Operating Data

Day	Time	Temperature Degrees F	Tons/Hr Kiln Feed	Kiln	Cyclone D/P	Scrubber Inlet	Pressure, Inches of Water	Fan Inlet	HEME D/P	Scrubber D/P	Fan RPM	Stack ACFM	Gas % Open	
15-Jul	16:00	111.1	510.6	0.69	0.72	1.5	12	19.2	25.8	7.2	10.5	810	350	
15-Jul	17:00	125.2	503.3	0.81	0.71	1.5	13	19	18.8	6	11.5	930	524	
15-Jul	18:00	108.7	429.3	0.79	0.31	1.5	14	13.9	25.5	-0.1	12.5	970	524	
15-Jul	22:00	107	436	0.69	0.67	1	2	12	15.3	25.4	3.3	10	810	524
15-Jul	23:00	107.6	545.8	0.74	0.62	1.5	2	13	17.6	25.7	4.6	11	810	524
15-Jul	24:00	109.7	542.4	0.75	0.63	1.5		12	16.1	26.1	4.1	12	820	524
16-Jul	01:00	114	512	0.5	0.558	1.5	1.5	9	30.3	18.6	21.3	7.5	780	474
16-Jul	02:00	115	487	0.27	0.408	1.5	1.5	0.7	29.5	19.2	28.8	-0.8	780	496
16-Jul	03:00	110	516	0.44	0.464	1	1.5	0.5	22.1	9.6	21.6	-1	520	449
16-Jul	04:00	111	546	0.45	0.556	1.2	1.5	0.7	33.3	9.5	32.6	-0.8	520	410
16-Jul	05:00	111	557	0.55	0.515	1	1.5	5	25	11.1	20	3.5	550	393
16-Jul	06:00	110	502	0.75	0.77	1.5	1.5	12	25.5	18.3	13.5	10.5	1030	522
16-Jul	07:00	113	467	0.86	0.45	1.4	1.5	13.5	25	26	11.5	12	1030	394
16-Jul	08:00	114	470	0	0.36	1	1.5	11	22.4	23.3	11.4	9.5	940	140
16-Jul	09:00	126	420	0	0.57	1	1.5	10.5	17.9	18.4	7.4	9	800	139
16-Jul	10:00	113	402	0.68	0.4	1.5	1.5	11	18.5	18.1	7.5	9.5	800	148
16-Jul	11:00	116	475	0.83	0.572	1.6	1.5	12	19.9	17.9	10.5	790	172	55
16-Jul	12:00	118	454	0.71	0.56	1.5	1.5	13	20.2	18	7.2	11.5	790	175
16-Jul	13:00	115	472	0	0.41	1.2	1.5	9	21.2	18.1	12.2	7.5	790	288
16-Jul	14:00	119	495	0.64	0.455	1.5	1.5	12	22	17.7	10	10.5	790	221
16-Jul	15:00	122	510	0.68	0.425	1	1.5	11	22	18	11	9.5	790	174
16-Jul	16:00	122	480	0.66	0.524	0.9	1.5	9.5	22.8	18	13.3	8	790	496
16-Jul	17:00	121	497	0.59	0.64	1.4	1.5	11	23.5	18	12.5	9.5	790	380
16-Jul	18:00	118	489	0.47		1.5				0	-1.5		42	
16-Jul	19:00	115	492	0.8		1.5				0	-1.5		50	
16-Jul	20:00	115	562	0.65		1.5				0	-1.5		50	
16-Jul	21:00	115	467	0.74		1.5				0	-1.5		50	
16-Jul	22:00	115	570	0.34	0.446	2	1.5	14	38.3	25.9	24.3	12.5	1250	521
16-Jul	23:00	120	501	0.77	0.548	1.3		10	26.3	18.1	16.3	10	790	521
16-Jul	24:00	114	477	0.55	0.657	1.5		9	29	18.3	20	9	790	521
17-Jul	01:00	114	506	0.64	0.32	2	1.5	12	14	15	2	10.5	680	500
17-Jul	02:00	115	508	0.55	0.24	1	1.5	12	13	13	1	10.5	650	327
17-Jul	03:00	114	493	0.53	0.2	1	1.5	11	12.6	15	1.6	9.5	610	283
17-Jul	04:00	114	552	0.53	0.25	1	1.5	10	12	19	2	8.5	590	255
17-Jul	05:00	112	511	0.61	0.25	1	1.5	10	12	18	2	8.5	630	316
17-Jul	06:00	112	542	0.51	0.499	0.9	1.5	6	27	11.5	21	4.5	550	386

Rapid Start Plant Operating Data

Day	Time	Zone				Bed				Temperature, Degrees F				ID Fan Outlet		
		1	2	3	4	1	2	3	4	5	4	5	Kiln Exit	Cyclone Exit	Scrubber Inlet	Scrubber Outlet
17-Jul	07:00	1071	1086	1076	1086						348	305	217.6	121.3	121	
17-Jul	08:00	1070	1088	1076	1081						345	217	219	120	122	
17-Jul	09:00	1066	1088	1078	1084						339	217	209	131	130	
17-Jul	10:00	1083	1096	1085	1081						333	190	196	161	129	
17-Jul	11:00	1092	1083	1065	1068						335	201	205	123	127	
17-Jul	12:00															
17-Jul	13:00	1046	954	1070	1074						406.3	225	236	105	132	
17-Jul	14:00	986	1144	1066	1092						375.5	226	236	118	149	
17-Jul	15:00	1122	1058	1037	1082						385	226	229	119	145	
17-Jul	16:00	1074	1108	1081	1079						421	242	257	118	145	
17-Jul	17:00	1070	1073	1067	1085						397	232	254	117	133	
17-Jul	18:00	1069	1090	1080	1079						383	224	248	117	146	
17-Jul	19:00	1073	1109	1070	1075						404	215	237	108	143	
17-Jul	20:00	1070	1101	1064	1088						370	225	241	128	141	
17-Jul	21:00	1068	1102	1074	1083						342	220	230	121	130	
17-Jul	22:00	1067	1090	1072	1082						339	218	227	121	134	
17-Jul	23:00	1078	1105	1071	1077						363	222	228	121	145	
17-Jul	24:00	1071	1095	1065	1075						329	224	221	122	147	
18-Jul	01:00	1088	1107	1072	1076						344.1	197.3	204.9	123.2	123.5	
18-Jul	02:00	1077	1103	1077	1084						329.8	195.8	200.9	123.3	126.7	
18-Jul	03:00	1063	1094	1063	1074						334	191	202	124	123	
18-Jul	04:00	1077	1098	1066	1071						335	198	199	124	124	
18-Jul	05:00															
18-Jul	06:00	1125	1087	1055	1100						325	201	203	126	122	
18-Jul	07:00	1117	1080	1065	1100						323	205	192	128	123	
18-Jul	08:00	1110	1090	1083	1112						321	204	201	123	128	
18-Jul	09:00										348	200	198	121	123	
18-Jul	10:00	1115	1041	1081	1100						208	208	212	212	115	
18-Jul	11:00										385	193	215	112	117	
18-Jul	12:00	1100	1088	1085	1093						386	195	223	122	121	
18-Jul	13:00										388	197	225	124	124	
18-Jul	14:00	1090	1084	1088	1100						349	196	220	124	125	
18-Jul	15:00	1093	1101	1101	1090											
18-Jul	16:00	1072	1066	1074	1090											
18-Jul	17:00	1096	1074	1063	1084											
18-Jul	18:00	1069	1094	1081	1083						364	214	223	122	116	
											371	211	223	121	124	

DOWNPOUR WETTED SOIL TO THE POINT IT

## Rapid Start Plant Operating Data

Day	Time	Pressure, Inches of Water										Stack ACFM	Gas % Open
		Temperature Degrees F	Kiln Stack	Tons/Hr Kiln Feed	Kiln Ash	Cyclone D/P	Scrubber Inlet	HEME Inlet	Fan Inlet	HEME D/P	Scrubber D/P		
17-Jul	07:00	115	507.6	0.54	0.5	0.9	1.5	9	27.6	12	18.6	7.5	550
17-Jul	08:00	126	499	0.52	0.51	1	0.75	7	29.3	14.5	22.3	6.25	610
17-Jul	09:00	124	541	0.52	0.49	1	0.75	5	30.3	10.4	25.3	4.25	540
17-Jul	10:00	128	526	0.49	0.507	1	0.75	15	38.8	8.9	23.8	14.25	550
17-Jul	11:00	122	390	0.53	1	0.75	0.75	15	28.4	4.9	13.4	14.25	390
17-Jul	12:00	FORMED A RING INSIDE THE REACTOR										0	0
17-Jul	13:00	109	319	0	0.58	1.25	0.75	18	56.1	26.1	38.1	17.25	1000
17-Jul	14:00	114	335	0.54	0.503	1.25	0.75	13	49.8	14.7	36.8	12.25	780
17-Jul	15:00	119	434	0.37	0.5	1.25	0.75	25	61.3	26	36.3	24.25	1080
17-Jul	16:00	119	462.6	0.1	0.43	1.25	0.75	25	72.9	26	47.9	24.25	1130
17-Jul	17:00	118	467.5	0.51	0.43	1.25	0.75	25	75	26	50	24.25	960
17-Jul	18:00	117	472	0.49	0.6	1.25	1.5	21	73.8	25.9	52.8	19.5	1000
17-Jul	19:00	117	509	0.03	0.461	0.75	1.5	17	79.9	19.3	62.9	15.5	890
17-Jul	20:00	114	458	0.57	0.43	2	1.5	18	68.2	21.5	50.2	16.5	940
17-Jul	21:00	114	506	0.39	0.451	2	1.5	16	70	21	54	14.5	940
17-Jul	22:00	119	508	0.67	0.471	2	1.5	15	71	21	56	13.5	950
17-Jul	23:00	119	498	0.66	0.343	2	1.5	12	72	17	60	10.5	870
17-Jul	24:00	121	518	0.54	0.324	1	1.5	11	72	17	61	9.5	870
18-Jul	01:00	115.6	594.8	0.55	0.25	1	1.4	10	13	25.8	3	8.6	530
18-Jul	02:00	115.7	618.7	0.51	0.21	1	1.4	11	13.9	28.1	2.9	9.6	550
18-Jul	03:00	116	564	0.64	0.25	1	1.4	11	13	25	2	9.6	490
18-Jul	04:00	119	537	0.58	0.23	1	1.4	12	13	21	1	10.6	520
18-Jul	05:00										0	10.6	183
18-Jul	06:00	114	528	0.65	0.2	1	1.5	11	13	20	2	9.5	590
18-Jul	07:00	116	512	0.59	0.29	1	1.5	11	13	23	2	9.5	640
18-Jul	08:00	118	527	0.65	0.27	1	1.5	11	14	24	3	9.5	630
18-Jul	09:00	118	499	0.51	0.29	1	1.5	11	11	21	0	9.5	640
18-Jul	10:00	115	435	0	0.29	1	0.75	11	10	22	-1	10.25	670
18-Jul	11:00	110	293	0	0.27	1	0.75	10	11	25	1	9.25	560
18-Jul	12:00	118	392	0	0.23	1	1.25	10	10	25	0	8.75	560
18-Jul	13:00	119	464	0.42	0.23	1	1.25	10	10	25	0	8.75	560
18-Jul	14:00	117	486	0.5	0.25	1.25		11	25	11	-1.25	620	328
18-Jul	15:00										0	0	50
18-Jul	16:00										0	0	50
18-Jul	17:00	115	467	0.33	0.3	1	10	19	25.9	9	10	570	274
18-Jul	18:00	115	461	0.42	0.228	1	1.3	10	37.3	26	27.3	8.7	650
18-Jul													374

## Rapid Start Plant Operating Data

Day	Time	Zone				Bed				Temperature, Degrees F				Cyclone Exit	Kiln Exit	Scrubber Inlet	Scrubber Outlet	ID Fan Outlet
		1	2	3	4	1	2	3	4	5	4	3	2					
18-Jul	19:00	1076	1085	1071	1080									361	214	226	123	126
18-Jul	20:00	1073	1098	1069	1078									356	207	219	121	125
18-Jul	21:00	1076	1104	1075	1081									367	209	226	119	124
18-Jul	22:00	1080	1105	1065	1076									360	214	221	122	126
18-Jul	23:00	1076	1092	1073	1074									348	204	215	123	126
18-Jul	24:00	1081	1090	1070	1071									335	196	204	125	123
19-Jul	01:00	1075	1104	1079	1084									363.6	206.1	201.7	121	121
19-Jul	02:00	1074	1096	1062	1085									357.9	212.5	207.2	122.2	121.3
19-Jul	03:00	1081	1091	1070	1072									349.7	199.7	206.7	123.6	122.3
19-Jul	04:00	1075	1097	1067	1086									347.7	195.9	202.4	122.8	122.6
19-Jul	05:00	1076	1092	1063	1082									345.6	203	199.5	123.2	123.1
19-Jul	06:00	1145	1143	1098	1125									358	204	209	119	115
19-Jul	07:00	1063	1108	1112	1124									369	215	221	122	121
19-Jul	08:00	1066	1106	1079	1097									359	219	225	124	122
19-Jul	09:00	1079	1116	1079	1098									365	216	225	122	121
19-Jul	10:00	1083	1108	1089	1108									375	221	231	118	118
19-Jul	11:00	1089	1112	1063	1086									358	210	227	120	122
19-Jul	12:00	1082	1095	1061	1084													
19-Jul	13:00	1080	1095	1070	1084									351	204	218	120	121
19-Jul	14:00	1087	1094	1070	1113									353	207	220	121	122
19-Jul	15:00	1080	1097	1075	1100									352	197	215	121	122
19-Jul	16:00	1078	1094	1068	1101									347	202	214	121	123
19-Jul	17:00	1129	1094	1066	1096									358	203	214	121	122
19-Jul	18:00	1118	1108	1071	1099									365	206	215	121	121
19-Jul	19:00	1068	1093	1073	1061									375	207	215	119	121
19-Jul	20:00	1069	1086	1062	1068									360	210	220	122	125
19-Jul	21:00	1063	1094	1063	1079									345	200	213	121	121
19-Jul	22:00	1070	1100	1071	1092									343	195	205	121	121
19-Jul	23:00	1081	1101	1069	1070									350	194	201	122	121
19-Jul	24:00	1078	1107	1079	1084									349	193	197	121	121
20-Jul	01:00	1078	1109	1077	1087									363	235	215	118	118
20-Jul	02:00	1064	1109	1069	1083									360	233	216	119	118
20-Jul	03:00	1070	1096	1065	1081									355	237	214	118	119
20-Jul	04:00	1070	1098	1063	1075									352	232	209	117	119
20-Jul	05:00	1069	1093	1063	1077									351	231	207	118	119
20-Jul	06:00	1073	1090	1081	1093									354	211	213	123	122

## Rapid Start Plant Operating Data

Day	Time	Temperature Degrees F	Tons/Hr Kiln Feed	Kiln	Cyclone D/P	Scrubber Inlet	HEME Inlet	Fan Inlet	HEME D/P	Scrubber D/P	Fan RPM	Stack ACFM	Gas % Open
18-Jul	19:00	115	484	0.44	0.28	1	1.3	10	46.2	26	36.2	8.7	690
18-Jul	20:00	117	478	0.36	0.287	1	1.3	11	50.2	24.8	39.2	9.7	680
18-Jul	21:00	116	529	0.52	0.28	1	1.3	11	57	24	46	9.7	710
18-Jul	22:00	116	482	0.43	0.23	1	1.3	10	57	24	47	8.7	710
18-Jul	23:00	117	517	0.62	0.23	1	1.4	11	64	22	53	9.6	730
18-Jul	24:00	111	498	0.51	0.21	1	1.4	11	13.3	25.1	2.3	9.6	530
19-Jul	01:00	117.5	483.9	0.42	0.22	0.5	2.8	34	36.7	5.2	2.7	31.2	590
19-Jul	02:00	115.8	471.5	0.79	0.25	0.5	2.8	38	41.9	5.5	3.9	35.2	620
19-Jul	03:00	118.4	517.1	0.72	0.26	0.5	2.8	38	37.9	5.4	-0.1	35.2	620
19-Jul	04:00	118.4	493.4	0.81	0.3	0.5	2.8	35	39.2	5.5	4.2	32.2	620
19-Jul	05:00	119.2	537.5	0.69	0.28	0.5	2.8	35	39.2	5.6	4.2	32.2	620
19-Jul	06:00	108	212	0.5	0.3	0.75	1.5	9	13.6	22	4.6	7.5	570
19-Jul	07:00	115	502	0.5	0.23	0.75	1.5	11	12.9	13	1.9	9.5	580
19-Jul	08:00	117	591	0.49	0.33	0.75	1.5	11	13.8	5.7	2.8	9.5	530
19-Jul	09:00	119	566	0.46	0.225	0.75	1.5	11	12.8	4.7	1.8	9.5	498
19-Jul	10:00	120	602	0.48	0.314	0.75	2.75	13	14.8	4.6	1.8	10.25	530
19-Jul	11:00	119	627	0.4	0.309	0.75	2.75	36	39.9	5.4	3.9	33.25	580
19-Jul	12:00										0	0	200
19-Jul	13:00	119	589	0.54	0.28	0.75	2.75	37	41.3	5.3	4.3	34.25	600
19-Jul	14:00	120	596	0.5	0.23	0.75	2.75	37	38.7	4.9	1.7	34.25	600
19-Jul	15:00	120	566	0.54	0.25	0.5	2.75	35	38.1	5	3.1	32.25	600
19-Jul	16:00	120	602	0.52	0.26	0.75	2.75	35	39.3	5	4.3	32.25	600
19-Jul	17:00	119	590	0.49	0.24	0.75	2.75	37	39.9	5.2	2.9	34.25	600
19-Jul	18:00	118	499	0.49	0.237	0.5	2.8	37	40.6	5.2	3.6	34.2	600
19-Jul	19:00	118	508	0.43	0.24	0.5	2.8	37	39	5.6	2	34.2	570
19-Jul	20:00	118	508	0.6	0.22	0.5	2.8	41	5.1	0	38.2	660	
19-Jul	21:00	119	501	0.56	0.264	0.5	2.8	36	41.6	5.8	5.6	33.2	640
19-Jul	22:00	117	501	0.58	0.266	0.5	2.8	35	40.6	5	5.6	32.2	580
19-Jul	23:00	117	532	0.48	0.204	0.5	2.8	35	40.1	5	5.1	32.2	640
19-Jul	24:00	116	491	0.51	0.227	0.5	2.8	35	36.6	5.1	1.6	32.2	590
20-Jul	01:00	113	459	0.266	0.9	2.8	35	36	5.5	1	32.2	620	
20-Jul	02:00	115	465	0.75	0.229	0.9	2.8	35	34.7	5.1	-0.3	32.2	590
20-Jul	03:00	115	503	0.63	0.25	0.9	2.8	34	34.6	5.2	0.6	31.2	590
20-Jul	04:00	115	501	0.66	0.221	0.9	2.8	40	40.3	5.2	0.3	37.2	600
20-Jul	05:00	115	513	0.74	0.23	1	2.8	40	41.6	5.2	1.6	37.2	600
20-Jul	06:00	119	454	0.65	0.21	1	2.8	36	35.2	5.9	-0.8	33.2	630

## Rapid Start Plant Operating Data

Day	Time	Temperature, Degrees F					Cyclone Inlet	Scrubber Inlet	Scrubber Outlet	ID Fan Outlet	
		Zone 1	Zone 2	Zone 3	Zone 4	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5	
20-Jul	07:00	1077	1075	1066	1093					364	207
20-Jul	08:00	1073	1097	1085	1098					355	216
20-Jul	09:00	1073	1083	1069	1079					389	212
20-Jul	10:00	1076	1081	1072	1081					351	209
20-Jul	11:00	1074	1065	1074	1078					437	245
20-Jul	12:00	1083	1062	1068	1070					360	219
20-Jul	15:00	1030	1170	1067	1050					352	223
20-Jul	16:00	1094	1065	1055	1070					352	220
20-Jul	17:00	1084	1031	1050	1063					352	221
20-Jul	18:00	1084	1085	1054	1062					361	227
20-Jul	19:00	1074	1105	1077	1070					357	243
20-Jul	20:00	1074	1099	1072	1075					348	232
20-Jul	21:00	1069	1098	1062	1068					357	240
20-Jul	22:00	1081	1103	1075	1111					360	242
20-Jul	23:00	1065	1199	1070	1064						
20-Jul	24:00										
21-Jul	01:00	1069	1090	1082	1081					362	252
21-Jul	02:00	1068	1092	1078	1077					359	254
21-Jul	03:00	1070	1095	1072	1080					353	246
21-Jul	04:00	1068	1098	1072	1081					355	249
21-Jul	05:00	1071	1096	1073	1087					359	251
21-Jul	06:00	1080	1090	1061	1073					351.5	225.2
21-Jul	07:00	1078	1092	1071	1080					347	228.3
21-Jul	08:00	1077	1088	1075	1096					338.8	216.3
21-Jul	09:00	1054	1087	1067	1091					336.3	306
21-Jul	10:00	1068	1085	1064	1090					338.3	202.4
21-Jul	11:00	1093	1109	1085	1120					350.5	208.7
21-Jul	12:00	1072	1104	1089	1090					342.1	218.1
21-Jul	13:00	1086	1110	1101	1093					349.2	223.7
21-Jul	14:00	1091	1113	1112	1090					355.7	231.8
21-Jul	15:00	1105	1123	1104	1100					362	230.7
21-Jul	16:00	1095	1114	1097	1107					362.5	224.7
21-Jul	17:00	1101	1088	1082	1067					362.3	241.9
21-Jul	18:00	1101	1085	1082	1077					363	241
21-Jul	19:00	1070	1103	1072	1080					355	240
21-Jul	20:00	1070	1112	1077	1081					359	245

Rapid Start Plant Operating Data

Day	Time	Temperature			Pressure, Inches of Water			Fan RPM			Stack ACFM		Gas % Open
		Degrees F	Kiln Stack	Tons/Hr Kiln Feed	Kiln D/P	Cyclone Scrubber Inlet	HME Inlet	Fan Outlet	HME D/P	Scrubber D/P	Fan RPM	Stack ACFM	
20-Jul	07:00	118	466	0.57	0.22	1	2.8	36	35.7	5.9	-0.3	33.2	630
20-Jul	08:00	119	509	0.61	0.21	0.9	2.6	36	39.2	5.6	3.2	33.4	630
20-Jul	09:00									0	0		
20-Jul	10:00	117	446	0.74	0.26	0.9	2.8	36	37	5.4	1	33.2	640
20-Jul	11:00	119	491	0.69	0.25	1	3	40	40	5.6	0	37	640
20-Jul	12:00									0	0		
20-Jul	15:00	116	342	0.65	0.28	0.9	3.1	36	37.4	5.3	1.4	32.9	630
20-Jul	16:00	119	486	0.69	0.31	0.9	3.2	38	37.3	5.3	-0.7	34.8	630
20-Jul	17:00	117	492	0.72	0.22	0.9	3	40	40.2	5.7	0.2	37	650
20-Jul	18:00	116	479	0.71	0.229	0.9	2.9	38	39.4	5.4	1.4	35.1	640
20-Jul	19:00	115	487	0.67	0.24	0.9	2.9	40	40.1	5.8	0.1	37.1	640
20-Jul	20:00	117	488	0.79	0.245	0.9	2.9	40	41.3	5.6	1.3	37.1	640
20-Jul	21:00	117	493	0.69	0.236	0.9	2.9	40	41.1	5.8	1.1	37.1	630
20-Jul	22:00	117	511	0.66	0.24	0.9	2.9	38	37.7	5.5	-0.3	35.1	630
20-Jul	23:00	116	550	0.68	0.247	0.9	2.9	39	38	5.6	-1	36.1	640
20-Jul	24:00									0	-2.9		
21-Jul	01:00	115	510	0.83	0.266	0.9	2.9	35	41	5.5	6	32.1	620
21-Jul	02:00	116	493	0.69	0.229	0.9	2.9	35	43	5.1	8	32.1	590
21-Jul	03:00	116	492	0.76	0.25	0.9	2.9	34	39	5.2	5	31.1	590
21-Jul	04:00	116	483	0.83	0.221	0.9	2.9	40	37	5.2	-3	37.1	600
21-Jul	05:00	115	565	0.67	0.23	1	2.9	40	42	5.2	2	37.1	600
21-Jul	06:00	115.1	565.5	0.88	0.244	0.9	2.8	41	43	5.3	2	38.2	600
21-Jul	07:00	117.3	492.6	0.78	0.211	1	3	41	43.3	5.2	2.3	38	600
21-Jul	08:00	116.7	504	0.76	0.24	0.5	2.8	41	42.9	5.4	1.9	38.2	600
21-Jul	09:00	112	513.1	0.84	0.226	0.6	2.7	40	41.4	5.2	1.4	37.3	600
21-Jul	10:00	118.1	479.8	0.81	0.5	2.9	40	43.3	5.4	3.3	37.1	610	140
21-Jul	11:00	118.7	477.2	0.83	0.227	0.5	2.8	39	43.6	5.3	4.6	36.2	610
21-Jul	12:00	117.5	505.1	0.83	0.19	0.5	2.8	40	43.1	5.3	3.1	37.2	610
21-Jul	13:00	119	493	0.81	0.2	0.6	2.8	41	42.7	5.5	1.7	38.2	610
21-Jul	14:00	107.6	501	0.82	0.243	0.9	2.8	48	43.8	12.1	-4.2	45.2	680
21-Jul	15:00	117.6	496.2	0.66	0.25	0.9	2.9	48	47.3	11.3	-0.7	45.1	690
21-Jul	16:00	116.9	535.6	0.8	0.27	0.5	2.8	44	44.9	11.5	0.9	41.2	670
21-Jul	17:00	116.3	526.7	0.81	0.27	0.5	2.8	48	44.6	11.8	-3.4	45.2	680
21-Jul	18:00	116	489	0.87	0.224	0.5	2.9	39	36.9	12.6	-2.1	36.1	640
21-Jul	19:00	115	515	0.8	0.234	0.5	2.9	42	43.1	12.5	1.1	39.1	640
21-Jul	20:00	115	505	0.86	0.25	0.5	2.9	40	42	13	2	37.1	680

Rapid Start Plant Operating Data

Day	Time	Zone				Bed				Temperature, Degrees F				ID Fan Outlet	
		1	2	3	4	1	2	3	4	5	Kiln Exit	Cyclone Exit	Scrubber Inlet	Scrubber Outlet	
21-Jul	21:00	1072	1103	1069	1075						361	251	201	119	123
21-Jul	22:00	1077	1099	1066	1075						358	244	201	119	122
21-Jul	23:00	1080	1118	1074	1083						360	238	197	118	121
21-Jul	24:00	1071	1109	1079	1087						362	247	203	118	122
22-Jul	01:00	431	418	384	354	486	448	433	431	403	301	226	201	107	118
22-Jul	02:00	351	339	310	289	384	362	349	336	318	254	199	176	107	115
22-Jul	03:00	294	270	256	244										
22-Jul	06:00	1071	1101	1076	1091	453	736	688	831	831	359.3	248.9	199.7	118	122
22-Jul	07:00	1076	1110	1081	1098	464	729	695	832	827	361.3	252.5	200.5	118.1	122.1
22-Jul	08:00	1076	1109	1084	1105	481	732	693	827	846	366.8	259.1	205.3	118.6	122.7
22-Jul	09:00	1088	1107	1091	1107	452	740	756	896	859	373	249.6	211.9	118.1	122.3
22-Jul	10:00	1085	1097	1086	1089	441	738	705	874	835	365.5	284.9	219.4	118.9	125
22-Jul	11:00	1083	1093	1092	1098	435	637	709	838	852	365.9	275.9	220.7	118.7	124.6
22-Jul	12:00	1080	1085	1081	1092	464	740	704	834	856	366.2	244.5	219.7	118.6	124.6
22-Jul	13:00	1097	1090	1096	1095	480	736	694	827	854	369.4	250.1	224.1	119	120.7
22-Jul	14:00	1081	1094	1100	1101	467	735	732	861	875	370.1	251.4	223.7	118.7	130.4
22-Jul	15:00	1083	1092	1097	1078	461	708	719	858	860	370.3	244.6	220.4	118.5	127.6
22-Jul	16:00	1083	1097	1100	1041	477	713	727	851	859	367.2	247.4	221.4	118.3	123.5
22-Jul	17:00	1079	1098	1101	1063	460	721	723	853	856	370.9	253.6	224	118.5	123.9
22-Jul	18:00	1081	1095	1084	1074	482	737	701	842	851	368	245	216	117	121

Rapid Start Plant Operating Data

Day	Time	Temperature				Pressure, Inches of Water				Fan RPM	Stack ACFM	Gas % Open
		Degrees F	Kiln Feed	Tons/Hr	Kiln	Cyclone D/P	Scrubber Inlet	HEME Inlet	Fan Outlet			
21-Jul	21:00	116	530	0.82	0.263	0.5	2.9	40	38	14	-2	37.1
21-Jul	22:00	116	513	0.8	0.25	0.7	2.9	39	38	13	-1	36.1
21-Jul	23:00	115	496	0.67	0.255	0.5	2.9	37	38	12	1	34.1
21-Jul	24:00	114	495	0.76	0.259	0.6	2.9	41	39	13	-2	38.1
22-Jul	01:00	108	144	0.02	0.063	0.5	2.6	3	34.1	22.9	31.1	0.4
22-Jul	02:00	107	116	0.02	0.02	0.5	2.6	3	33.5	23.3	30.5	0.4
22-Jul	03:00					2.6			0		0	-2.6
22-Jul	06:00	114.8	568	0.69	0.229	0.75	2.75	40	40	14	0	37.25
22-Jul	07:00	115.1	509.6	0.68	0.265	0.75	2.75	40	40.9	13.6	0.9	37.25
22-Jul	08:00	115.8	534	0.73	0.226	0.75	2.75	40	38.6	13.8	-1.4	37.25
22-Jul	09:00	116.4	502.6	0.76	0.273	0.75	2.75	3	39.6	13.7	36.6	0.25
22-Jul	10:00	119.4	512.3	0.71	0.285	0.75	2.75	3	38.7	17.5	35.7	0.25
22-Jul	11:00	119.4	473.6	0.75	0.26	0.75	2.75	3	37.5	15.7	34.5	0.25
22-Jul	12:00	119.2	474.5	0.72	0.25	0.75	2.75	3	40.2	17.8	37.2	0.25
22-Jul	13:00	119	477.7	0.71	0.24	0.75	2.75	3	40.5	17	37.5	0.25
22-Jul	14:00	120.1	500.3	0.81	0.29	0.75	2.75	3	36.8	14.8	33.8	0.25
22-Jul	15:00	119.7	476.3	0.8	0.257	0.75	2.75	3	36.7	15.3	33.7	0.25
22-Jul	16:00	117.8	481.4	0.83	0.29	0.75	2.75	3	37.8	15.9	34.8	0.25
22-Jul	17:00	117.2	491.8	0.81	0.27	0.75	2.75	3	39.6	15.6	36.6	0.25
22-Jul	18:00	114	540	0.76	0.255	0.5	2.8	3	41.3	13.9	38.3	#VALUE!
												680
												176
												50

**APPENDIX C**

**FULL SCALE PLANT OPERATING DATA**

## **FULL SCALE PLANT OPERATING DATA**

The plant data logger recorded operating data every half hour during the entire period of plant operation. To provide a sample of that data, this appendix contains data recorded by the data logger during the June 1996 stack tests. This provides a snapshot of the operation between June 9 and 18, 1996. The number of the instrument that collected the data is shown on each sheet below the data title. These numbers can be found on the P&IDs to locate where the data were taken.

Some data were not automatically recorded and, from time to time, these data were recorded manually. The manual data is also contained in these appendices.

6/7/96	WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
7:30:00	40	106	119.0	1.7	205	1.92	0.8	0.4	0.3	4.6	5.8	6.0	0.0
8:00:00	40	105	118.0	1.7	204	1.92	1	0.4	0.3	4.4	5.9	6.0	0.1
8:30:00	40	105	118.0	1.7	208	1.89	1.2	0.5	0.3	4.5	5.8	5.9	0.1
9:00:00	40	105	117.0	0.5	209	1.90	0.9	0.5	0.3	4.2	6.2	6.2	0.0
9:30:00	40	105	118.0	1.7	215	1.89	1.3	0.3	0.3	5.5	6.4	6.5	0.1
10:00:00	40	104	119.0	1.7	207	1.91	1.1	0.3	0.3	4.7	5.8	5.9	0.1
10:30:00	40	105	117.0	1.4	199	1.81	1.4	0.3	0.3	3.0	5.3	5.4	0.1
11:00:00	39	105	117.0	1.6	221	1.87	1.2	0.3	0.3	5.6	6.5	6.5	0.1
11:30:00	40	105	215.0	1.7	199	1.92	0.9	0.3	0.3	4.8	5.6	5.5	0.0
12:00:00	40	105	119.0	1.1	226	1.87	1.4	0.3	0.3	5.0	5.8	5.9	0.1
12:30:00	40	105	116.0	0.9	214	1.97	1.2	0.3	0.2	4.5	5.2	5.3	0.1
13:00:00	37	104	115.0	0.8	215	1.94	1.2	0.4	0.2	4.0	5.6	5.7	0.0
13:30:00	41	106	271.0	1.7	228	1.94	1.4	0.3	0.3	4.7	6.1	6.2	0.1
14:00:00	40	106	118.0	1.7	214	1.94	1.2	0.3	0.2	4.7	5.2	5.2	0.0
14:30:00	41	106	124.0	1.7	210	1.88	1.3	0.3	0.3	4.7	5.6	5.5	0.0
15:00:00	41	106	119.0	1.6	215	1.82	1.4	0.3	0.2	4.9	5.7	5.8	0.1
15:30:00	40	105	117.0	0.3	215	1.86	1.4	0.3	0.2	4.9	5.8	5.9	0.0
16:00:00	40	106	123.0	1.3	224	1.87	1.3	0.2	0.2	5.2	5.9	6.0	0.1
16:30:00	40	106	118.0	1.7	218	1.98	1.1	0.3	0.2	4.7	5.8	5.8	0.0
17:00:00	40	106	117.0	1.3	210	1.94	1.3	0.2	0.2	4.3	5.9	6.0	.0.1
Average	39.95	105.30	130.75	1.38	212.80	1.90	1.20	0.33	0.26	4.65	5.80	5.86	0.06
Maximum	41	106	271	1.71	228	1.98	1.4	0.5	0.3	5.6	6.5	6.5	0.1
Minimum	37	104	115	0.29	199	1.81	0.8	0.2	0.2	3	5.2	5.2	0

## BCDP Operating Data During the Stack Test on June 7, 1996

		Klin Vacuum In H2O		Clone Out Degs F		WESP Out Degs F		Scrubber Out Degs F		Stack Out Degs F		ID Fan Out Degs F		#1 Bed Temp Degs F		#2 Bed Temp Degs F		#3 Bed Temp Degs F		#4 Bed Temp Degs F		#5 Bed Temp Degs F		#6 Bed Temp Degs F			
6/7/96		PI-210		PI-510		TI-512		TI-524		TI-554		TI-502		TI-582		T-212A		T-212B		T-212C		T-212D		T-212E		T-212F	
7:30:00	0.49	412.2	356	212	84	94	94	452	616	535	795	778	778	880													
8:00:00	0.57	412.1	354	212	84	98	98	452	616	535	795	778	778	880													
8:30:00	0.47	406.8	350	212	85	101	101	386	567	492	774	780	780	868													
9:00:00	0.52	411.8	351	213	85	103	103	396	579	509	785	791	791	887													
9:30:00	0.38	411.2	350	212	85	103	103	387	579	504	764	792	792	881													
10:00:00	0.47	415.8	351	212	86	104	105	386	594	566	786	828	828	902													
10:30:00	0.63	416	351	211	86	104	105	396	584	571	800	835	835	900													
11:00:00	0.36	422.6	353	213	86	103	106	425	628	566	803	843	843	915													
11:30:00	0.54	409.2	353	203	87	103	105	412	609	603	830	862	862	939													
12:00:00	0.30	414.8	354	212	87	103	104	412	618	591	809	845	845	926													
12:30:00	0.35	413.9	353	212	88	103	103	395	608	585	807	845	845	925													
13:00:00	0.37	413.7	352	214	88	100	100	395	607	579	810	843	843	917													
13:30:00	0.39	415.5	352	213	88	101	102	386	611	578	807	830	830	907													
14:00:00	0.35	408.5	350	212	88	100	102	409	616	578	750	814	814	893													
14:30:00	0.39	410.6	349	212	88	99	103	384	610	613	740	825	825	890													
15:00:00	0.31	420.9	358	212	88	100	101	399	617	558	860	872	872	916													
15:30:00	0.39	426.1	362	212	88	98	99	401	617	552	896	908	908	939													
16:00:00	0.30	436.2	367	211	88	100	98	459	651	576	939	930	930	951													
16:30:00	0.41	427.9	365	211	88	99	96	464	650	605	855	892	892	945													
17:00:00	0.50	417.2	360	211	89	96	93	421	610	582	814	821	821	906													
Average	0.42	416.15	354.41	211.50	87.08	100.71	101.05	410.85	609.35	563.90	810.95	835.60	835.60	908.35													
Maximum	0.63	436.2	366.8	213.6	88.6	104.4	106	464	651	613	939	930	930	951													
Minimum	0.3	406.8	348.7	202.9	84	93.7	93	384	567	492	740	740	740	868													

6/7/96	Ash Temp	WESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
	Degs F	TI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	AI-526B	FI-528
7:30:00	526.3	74	29	-1	86	72	30	877	8.3	6.0	3.1
8:00:00	526.8	73	35	-1	86	70	17	859	8.1	6.0	3.0
8:30:00	516.4	74	39	-1	91	70	22	849	8.1	6.0	3.0
9:00:00	525.7	73	29	-1	88	71	29	841	8.1	6.0	2.9
9:30:00	518.1	73	3	-1	87	72	55	831	8.1	6.0	3.1
10:00:00	545.6	73	38	-1	84	72	46	823	8.2	6.0	3.1
10:30:00	543.3	74	33	-1	83	73	47	786	8.1	6.0	2.7
11:00:00	540.9	69	48	-1	82	74	61	775	8.2	5.9	2.8
11:30:00	556.9	74	15	-1	81	73	75	767	8	6.2	3.4
12:00:00	558.3	73	31	-1	80	72	83	757	8.2	6.0	3.0
12:30:00	553.8	73	37	-1	80	72	60	749	8.2	6.0	3.0
13:00:00	554.6	60	57	-1	80	74	58	739	8.3	5.8	3.0
13:30:00	555.5	73	36	-1	79	72	64	1904	8	6.2	3.0
14:00:00	542.4	73	3	-1	79	73	70	1912	8.2	6.0	3.0
14:30:00	535.5	74	37	-1	78	73	78	1904	8.2	6.0	3.0
15:00:00	548.7	74	3	-1	77	73	84	1893	8.3	6.0	3.1
15:30:00	569.1	74	30	-1	77	73	90	1873	8.3	6.0	2.9
16:00:00	570.9	74	36	-1	77	73	86	1866	8.3	6.0	3.1
16:30:00	557.4	74	37	-1	76	73	80	1855	8.3	6.0	3.0
17:00:00	561.0	74	40	-1	76	74	76	1846	8.3	6.0	2.9
Average	545.36	72.65	30.80	-1.00	81.35	72.45	60.55	1235.30	8.19	6.01	3.01
Maximum	570.9	74	57	-1	91	74	90	1912	8.3	6.2	3.4
Minimum	516.4	60	3	-1	76	70	17	739	8	5.8	2.7

## BCDP Operating Conditions During the Stack Test on June 9, 1996

WESP Recycle GPM		Kiln Steam Lbs/Hr	WEsp Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
6/9/96	FI-521	FI-712	FI-714	SI-211	SI-582	WI-110	PI-582	PDI-510	PDI-532	PDI-542	PI-560	PI-581	PDI-572
8:30:00	40	105	331.0	1.1	191	1.60	2.9	0.4	0.4	2.6	5.9	5.9	0.0
9:00:00	40	106	374.0	1.6	200	1.89	3.3	0.2	0.3	3.8	5.9	5.9	0.0
9:30:00	40	104	274.0	1.7	179	1.92	1.5	0.4	0.2	3.1	6.7	6.8	0.1
10:00:00	40	105	265.0	1.5	220	2.01	2.5	0.4	0.4	5.2	5.3	5.3	0.0
10:30:00	40	106	258.0	1.7	178	1.85	1.3	0.4	0.3	5.9	7.2	7.3	0.1
11:00:00	40	106	207.0	1.7	195	1.90	2	0.3	0.2	4.8	6.6	6.6	0.0
11:30:00	40	106	190.0	1.0	187	1.90	1.6	0.4	0.2	5.7	6.7	6.9	0.0
12:00:00	40	105	196.0	1.5	210	1.98	2.6	0.5	0.3	5.7	5.3	5.3	0.0
12:30:00	40	102	120.0	1.5	178	1.80	2.1	0.3	0.2	2.1	4.2	4.4	0.2
13:00:00	40	106	164.0	1.8	197	1.76	2.2	0.3	0.3	5.0	5.5	5.4	0.0
13:30:00	40	105	175.0	1.3	179	1.84	2.3	0.4	0.3	2.8	6.1	5.8	0.0
14:00:00	40	105	167.0	1.5	202	1.89	2.2	0.4	0.3	4.4	5.7	5.7	0.0
14:30:00	40	104	117.0	1.8	184	1.88	2.7	0.4	0.3	3.3	5.7	5.6	0.0
15:00:00	40	105	143.0	1.8	188	1.89	1.7	0.4	0.2	4.7	5.9	5.9	0.0
15:30:00	40	106	167.0	1.8	207	1.89	2	0.3	0.2	7.7	8.5	8.6	0.1
16:00:00	40	106	199.0	1.7	179	1.83	1.6	0.4	0.1	2.7	6.1	6.4	0.3
Average	40.00	105.13	209.19	1.54	192.13	1.86	2.16	0.37	0.26	4.34	6.08	6.11	0.05
Maximum	40	106	374	1.77	220	2.01	3.3	0.5	0.4	7.7	8.5	8.6	0.3
Minimum	40	102	117	0.97	178	1.6	1.3	0.2	0.1	2.1	4.2	4.4	0

6/9/96	Kiln Vacuum In H ₂ O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
	PI-210	PI-510	PI-512	PI-524	PI-554	PI-502	PI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F
8:30:00	0.57	414.3	344	212	86	99	98	453	617	572	797	765	916
9:00:00	0.45	416.4	350	211	86	101	100	453	617	572	797	765	917
9:30:00	0.67	416.5	353	211	86	102	102	453	617	572	797	766	916
10:00:00	0.11	406.1	353	211	88	103	103	453	617	572	797	766	916
10:30:00	0.76	406.3	351	212	86	103	102	453	617	572	797	766	916
11:00:00	0.43	406.8	350	211	87	105	105	453	617	572	797	766	915
11:30:00	0.50	406.4	348	211	87	105	105	453	617	571	797	766	915
12:00:00	0.23	402.8	348	211	89	103	103	453	616	571	797	766	915
12:30:00	0.75	400.6	348	209	89	103	105	453	616	571	797	766	915
13:00:00	0.39	399.4	345	211	89	102	105	453	616	571	796	766	915
13:30:00	0.65	398.3	342	212	90	102	105	452	616	571	796	765	914
14:00:00	0.38	390.3	340	211	90	103	105	452	616	571	796	765	914
14:30:00	0.51	396.5	338	211	90	104	107	452	616	571	796	765	914
15:00:00	0.55	396.4	342	211	90	104	106	452	615	570	795	765	914
15:30:00	0.26	400.7	347	211	90	104	105	452	615	570	795	765	914
16:00:00	0.73	397.6	347	211	90	102	99	452	615	570	795	765	914
Average	0.50	403.46	346.50	211.13	88.17	103.03	103.44	452.63	616.25	571.19	796.38	765.50	915.00
Maximum	0.76	416.5	353	211.6	89.6	104.5	107	453	617	572	797	766	917
Minimum	0.11	390.3	338	209.1	86.2	98.9	98	452	615	570	795	765	914

6/9/96	Ash Temp Degs F	WESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
	TI-811	LI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	AI-526B	FI-528
8:30:00	539.8	73	40	5	88	78	69	1425	8.1	6.0	3.0
9:00:00	537.3	73	14	2	88	77	69	1398	8	6.0	3.1
9:30:00	580.7	73	39	4	86	76	69	1387	8	6.0	2.9
10:00:00	563.4	73	28	4	83	76	67	1380	8	6.1	3.2
10:30:00	573.2	73	3	2	83	75	66	1361	8	6.0	3.0
11:00:00	565.9	73	30	5	80	74	54	1351	8	6.0	3.0
11:30:00	553.3	73	40	4	80	74	44	1343	8	6.0	3.1
12:00:00	561.6	74	18	3	79	74	37	1332	8	6.0	3.1
12:30:00	556.0	73	22	-1	79	75	29	1325	8.1	6.0	3.0
13:00:00	553.0	73	25	3	77	75	22	1306	8.1	6.0	3.1
13:30:00	560.2	73	29	3	78	75	17	1296	8	6.0	2.8
14:00:00	548.4	73	32	3	77	76	17	1287	8.1	6.0	3.0
14:30:00	566.3	73	30	1	77	74	31	1278	8.1	6.0	3.0
15:00:00	545.6	73	25	2	76	74	53	1269	8	6.0	3.0
15:30:00	571.6	73	22	8	75	74	70	1258	8	6.0	3.0
16:00:00	575.5	73	25	1	75	74	54	1250	8.1	6.0	3.0
Average	559.49	73.06	26.38	3.06	80.06	75.06	48.00	1327.88	8.04	6.01	3.02
Maximum	580.7	74	40	8	88	78	70	1425	8.1	6.1	3.2
Minimum	537.3	73	3	-1	75	74	17	1250	8	6	2.8

6/11/96	WESP		Kiln		WE SP		Kiln		ID Fan		ID Fan		Clone		Pr Cond		Scrubber		Chill Cond		ID Fan		HEME	
	Recycle GPM	Steam Lbs/Hr	Steam Lbs/Hr	Steam Lbs/Hr	Rotation RPM	Rate Tons	In H2O	Out H2O	D/P	D/P	In H2O	D/P	In H2O	D/P	In H2O	D/P	In H2O	In H2O	In H2O	D/P	In H2O	D/P	In H2O	
7:30:00	40	104	135.0	1.8	185	1.86	1.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	3.9	5.2	5.2	0.0	
8:00:00	40	104	117.0	1.8	207	1.91	1.3	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	4.6	5.8	5.7	0.0	
8:30:00	40	105	116.0	1.8	204	1.91	1.1	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	4.8	6.0	6.1	0.1	
9:00:00	40	104	114.0	1.8	198	1.87	1.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	3.9	5.2	5.2	0.2	
9:30:00	39	110	118.0	1.8	208	1.91	1.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5.3	5.3	5.3	0.2	
10:00:00	39	105	116.0	1.8	207	1.90	1.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	5.1	5.6	5.6	0.1	
10:30:00	40	104	116.0	1.8	221	0.95	1.8	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5.7	5.7	5.7	0.1	
11:00:00	39	104	117.0	1.8	210	2.02	1.1	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	4.7	5.2	5.2	0.0	
11:30:00	39	103	115.0	1.8	213	1.93	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	4.3	5.3	5.4	0.1	
12:00:00	-8	105	114.0	1.8	244	1.88	1.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	5.2	5.9	5.9	0.0	
12:30:00	40	108	122.0	1.8	228	1.94	1.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5.2	5.8	5.9	0.1	
13:00:00	40	108	118.0	1.8	217	1.90	0.8	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	4.1	5.4	5.4	0.0	
13:30:00	40	110	121.0	1.8	249	1.90	1.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	5.1	5.4	5.3	0.0	
14:00:00	40	108	119.0	1.8	222	1.91	0.9	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	4.4	5.6	5.7	0.0	
14:30:00	40	107	118.0	1.8	220	1.79	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	4.2	5.4	5.4	0.0	
15:00:00	40	108	125.0	1.8	226	2.21	1.6	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.9	5.5	5.4	0.0	
Average	36.75	106.06	118.81	1.77	216.19	1.86	1.23	0.21	0.21	0.21	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	4.59	5.55	5.58	0.05	
Maximum	40	110	135	1.77	249	2.21	1.8	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	5.7	6	6.1	0.2	
Minimum	-8	103	114	1.77	185	0.95	0.8	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	2.9	5.2	5.2	0	

6/11/96	Kiln Vacuum In H2O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
PI-210	TI-510	TI-512	TI-524	TI-554	TI-502	TI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F	
7:30:00	0.70	386.5	331	210	84	93	91	524	677	559	762	792	869
8:00:00	0.38	382.9	333	211	85	97	93	534	701	582	790	805	870
8:30:00	0.40	384.4	333	210	85	95	92	528	670	567	795	808	890
9:00:00	0.48	376.7	326	210	86	97	95	443	640	566	801	813	895
9:30:00	0.34	378	327	211	86	99	96	427	617	521	739	777	870
10:00:00	0.32	378.8	326	211	87	103	98	414	631	532	743	783	863
10:30:00	0.24	377.4	325	210	87	105	99	425	629	529	740	785	858
11:00:00	0.34	375.2	322	212	89	107	101	414	633	534	781	817	886
11:30:00	0.38	370	319	211	90	105	96	410	615	528	755	780	878
12:00:00	0.16	369.4	311	210	89	96	90	396	625	530	737	776	858
12:30:00	0.29	377.5	311	212	89	100	98	398	599	521	762	775	871
13:00:00	0.57	384.5	319	213	90	104	102	426	622	508	736	754	852
13:30:00	0.25	378	318	213	90	105	105	415	598	508	741	765	854
14:00:00	0.59	374.4	317	212	91	102	98	407	604	500	722	754	853
14:30:00	0.59	379.1	316	212	90	100	103	439	611	510	742	766	847
15:00:00	0.60	385.9	318	211	90	99	99	468	641	535	775	780	870
Average	0.41	378.67	321.88	211.26	87.92	100.51	97.25	441.75	632.06	533.13	757.56	783.13	867.75
Maximum	0.7	386.5	332.8	213.1	90.6	107.2	105	534	701	582	801	817	895
Minimum	0.16	369.4	311.4	209.9	84.3	93.1	90	396	598	500	722	754	847

6/11/96	Ash Temp Degr F	WESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH In pH	pH Adj	pH Out pH	pH Adj
	Ti-811	Li-524	Li-530	Li-552	Li-610	Li-665	Li-680	Li-750	AI-526A	AI-526B	AI-526B	FI-528
7:30:00	546.5	75	38	2	100	75	39	1499	8.2	6.0	6.0	2.9
8:00:00	562.3	73	39	4	99	75	41	1491	8.2	6.0	6.0	3.0
8:30:00	573.6	73	30	3	99	74	44	1480	8.2	6.0	6.0	2.9
9:00:00	567.0	74	27	4	99	74	48	1480	8.2	6.0	6.0	2.9
9:30:00	542.2	74	30	4	98	72	44	1473	8.2	6.0	6.0	3.0
10:00:00	526.8	74	27	3	97	74	39	1455	8.2	6.0	6.0	3.1
10:30:00	534.2	74	17	3	96	75	42	1455	8.2	6.0	6.0	3.1
11:00:00	543.5	75	26	3	90	74	45	1445	8.2	6.0	6.0	2.9
11:30:00	542.7	74	36	5	89	73	45	1436	8.2	6.0	6.0	3.0
12:00:00	527.3	73	39	3	88	73	49	1424	8.2	6.0	6.0	3.1
12:30:00	526.6	73	36	3	87	73	51	1417	8.2	6.0	6.0	3.1
13:00:00	496.5	74	38	4	87	73	51	1408	8.1	6.0	6.0	2.9
13:30:00	491.3	73	36	2	85	73	52	1400	8.1	6.0	6.0	2.9
14:00:00	496.5	75	36	2	82	74	55	1388	8.1	6.0	6.0	3.0
14:30:00	493.5	73	35	1	78	73	51	1380	8.1	6.0	6.0	3.0
15:00:00	500.9	73	29	4	76	72	46	1369	8.2	6.0	6.0	3.0
Average	529.46	73.75	32.44	3.13	90.63	73.56	46.38	1437.50	8.18	6.00	6.00	2.99
Maximum	573.6	75	39	5	100	75	55	1499	8.2	6	6	3.1
Minimum	491.3	73	17	1	76	72	39	1369	8.1	6	6	2.9

## BCDP Operating Data During the Stack Test on June 12, 1996

6/12/96	WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChlCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
9:30:00	40	107	162.0	1.8	213	1.93	1	0.2	0.3	6.3	6.6	6.6	0.1
10:00:00	40	110	121.0	1.8	222	1.60	1.4	0.2	0.2	6.4	7.5	7.7	0.2
10:30:00	40	107	133.0	1.8	223	0.72	2.1	0.3	0.2	6.2	5.4	5.4	0.0
11:00:00	40	106	153.0	1.8	217	1.87	1.2	0.5	0.2	4.0	6.6	6.6	0.0
Average	40.00	107.50	142.25	1.77	218.75	1.53	1.43	0.30	0.23	5.73	6.53	6.58	0.08
Maximum	40	110	162	1.77	223	1.93	2.1	0.5	0.3	6.4	7.5	7.7	0.2
Minimum	40	106	121	1.77	213	0.72	1	0.2	0.2	4	5.4	5.4	0

6/12/96	Kiln In H2O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
	PI-210	PI-512	TI-524	TI-554	TI-502	TI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F	
9:30:00	0.36	392.6	337	210	87	98	99	502	686	641	768	812	906
10:00:00	0.24	395.2	338	211	88	102	102	498	689	669	802	827	922
10:30:00	0.27	387.7	331	211	88	105	104	502	701	703	836	852	904
11:00:00	0.45	399.1	333	210	89	101	103	516	756	724	834	844	889
Average	0.33	393.65	334.88	210.55	87.63	101.43	102.00	504.50	708.00	684.25	810.00	833.75	905.25
Maximum	0.45	399.1	338	211.3	88.7	104.5	104	516	756	724	836	852	922
Minimum	0.24	387.7	331.3	210	86.6	97.7	99	498	686	641	768	812	889

## BCDP Operating Data During the Stack Test on June 12, 1996

6/12/96	Ash Temp Degr F	WEsp Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
	Tl-811	LI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	AI-526B	FI-528
9:30:00	572.3	73	32	4	88	73	59	996	8.1	6.0	3.0
10:00:00	581.9	73	40	4	87	73	31	989	8.1	6.0	3.1
10:30:00	582.4	74	22	3	84	74	34	924	8.1	6.0	3.0
11:00:00	560.3	73	37	3	83	74	27	924	8.2	6.0	2.9
Average	574.23	73.25	32.75	3.50	85.50	73.50	37.75	958.25	8.13	6.00	3.00
Maximum	582.4	74	40	4	88	74	59	996	8.2	6	3.1
Minimum	560.3	73	22	3	83	73	27	924	8.1	6	2.9

Note: pH loop out of service

		WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
6/13/96	FI-521	FI-712	FI-714	SI-211	SI-582	WI-110	PI-582	PDI-510	PDI-532	PDI-542	PI-560	PI-581	PDI-572	
8:30:00	39	108	305.0	0.7	188	1.93	2.8	0.3	0.0	0.7	5.0	5.2	0.2	
9:00:00	39	106	327.0	0.1	189	1.93	3	0.1	0.1	3.9	4.9	5.2	0.3	
9:30:00	39	108	372.0	0.7	178	1.90	2.7	0.3	0.1	3.2	4.2	4.4	0.2	
10:00:00	39	102	373.0	1.0	186	1.90	2.7	0.3	0.1	3.3	4.6	4.8	0.2	
10:30:00	39	104	367.0	1.7	178	1.90	2.6	0.4	0.2	2.2	4.5	4.7	0.2	
11:00:00	39	106	361.0	1.7	178	1.90	2.8	0.3	0.2	2.7	3.5	3.7	0.6	
11:30:00	39	106	386.0	1.1	178	1.92	2.8	0.6	0.2	2.6	3.7	3.9	0.2	
12:00:00	39	104	342.0	1.8	178	1.92	2.7	0.3	0.2	2.6	3.8	4.0	0.2	
12:30:00	39	108	333.0	1.2	179	1.91	2.6	0.4	0.2	2.7	4.2	4.4	0.2	
13:00:00	39	102	214.0	1.5	178	2.09	2.2	0.5	0.2	4.6	5.5	5.7	0.2	
13:30:00	39	108	256.0	0.1	197	1.96	2.5	0.3	0.2	5.1	6.3	6.4	0.2	
14:00:00	39	108	207.0	0.7	207	1.90	2	0.2	0.3	4.2	5.6	5.8	0.2	
14:30:00	39	108	171.0	0.4	192	1.91	1.8	0.4	0.2	3.4	4.5	4.7	0.0	
15:00:00	39	103	219.0	0.6	201	1.90	2.2	0.4	0.2	3.6	4.8	5.0	0.0	
15:30:00	39	104	200.0	0.7	179	2.00	1.6	0.3	0.2	2.7	4.4	4.5	0.1	
16:00:00	39	104	193.0	1.3	179	1.99	1.5	0.6	0.2	2.8	4.4	4.5	0.1	
Average	39.00	105.56	289.13	0.96	185.31	1.94	2.41	0.36	0.18	3.33	4.62	4.81	0.19	
Maximum	39	108	386	1.76	207	2.09	3	0.6	0.3	5.1	6.3	6.4	0.6	
Minimum	39	102	171	0.09	178	1.9	1.5	0.1	0	2.2	3.5	3.7	0	

6/13/96	Kiln Vacuum In H2O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
PI-210	TI-510	TI-512	TI-524	TI-554	TI-502	TI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F	
8:30:00	0.43	409.5	355	210	91	100	91	547	677	666	792	828	862
9:00:00	0.39	403.6	352	209	91	102	94	566	683	674	794	824	881
9:30:00	0.69	404.2	351	210	91	104	94	577	703	694	814	852	915
10:00:00	0.42	407.2	353	210	91	104	94	590	696	699	827	864	933
10:30:00	1.05	417.3	354	210	91	106	95	592	706	697	838	870	940
11:00:00	0.63	413	357	210	91	106	95	569	694	681	824	844	920
11:30:00	0.56	413.9	358	210	91	105	95	586	706	700	848	872	945
12:00:00	0.88	412.2	356	210	91	105	95	574	708	692	843	875	957
12:30:00	0.76	409.6	357	210	91	104	96	573	707	696	848	872	954
13:00:00	0.66	413.8	358	210	91	103	96	557	708	691	826	861	944
13:30:00	0.36	411.2	356	210	91	103	97	536	671	681	819	878	950
14:00:00	0.27	408	356	210	91	104	100	549	683	674	820	851	934
14:30:00	0.47	407	351	210	92	104	102	537	668	669	810	848	926
15:00:00	0.42	404.2	347	210	92	103	102	532	673	673	803	848	927
15:30:00	0.82	413.1	350	209	92	102	99	573	694	684	808	851	928
16:00:00	0.89	408.7	353	210	92	101	94	537	680	686	825	865	943
Average	0.61	409.78	354.00	209.88	91.03	103.34	96.19	562.19	691.06	684.81	821.19	856.44	928.69
Maximum	1.05	417.3	358.3	210.4	92.1	106	102	592	708	700	848	878	957
Minimum	0.27	403.6	347.4	209.1	90.7	100.1	91	532	668	666	792	824	862

6/13/96	Ash Temp Degr F	WESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
TI-811	LI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	AI-526B	FI-528	
8:30:00	584.5	74	33	5	88	75	59	1480	7.6	8.0	4.8
9:00:00	564.3	74	31	3	95	74	53	1473	7.6	7.9	4.7
9:30:00	593.3	76	24	5	91	71	55	1454	7.6	7.9	4.8
10:00:00	595.5	73	14	3	83	71	57	1443	7.6	7.9	4.9
10:30:00	604.1	76	2	3	82	71	55	1436	7.6	7.8	4.9
11:00:00	608.8	75	31	3	80	71	55	1425	7.6	7.8	4.9
11:30:00	596.6	74	2	3	78	72	58	1417	7.6	7.8	4.8
12:00:00	621.6	75	31	1	76	72	56	1407	7.6	7.8	4.8
12:30:00	630.3	75	37	3	74	73	52	1388	7.6	7.8	4.8
13:00:00	605.5	74	2	5	69	75	58	1380	7.6	7.8	4.8
13:30:00	603.9	73	39	5	69	76	59	1369	7.6	7.8	4.8
14:00:00	596.3	72	33	2	68	73	55	1361	7.6	7.8	4.9
14:30:00	605.0	76	39	4	66	72	58	1351	7.6	7.8	4.8
15:00:00	613.3	74	22	4	62	72	52	1295	7.6	7.8	4.8
15:30:00	604.9	75	2	3	60	70	50	1257	7.6	7.8	4.9
16:00:00	614.1	75	36	4	59	72	54	1249	7.6	7.8	4.8
Average	602.63	74.44	23.63	3.50	75.00	72.50	55.38	1386.56	7.60	7.83	4.83
Maximum	630.3	76	39	5	95	76	59	1480	7.6	8	4.9
Minimum	564.3	72	2	1	59	70	50	1249	7.6	7.8	4.7

6/16/96	WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
FI-521	FI-712	FI-714	SI-211	SI-582	WI-110	PI-582	PDI-510	PDI-532	PDI-542	PI-560	PI-581	PI-572	
9:00:00	37	108	127.0	1.7	196	1.97	1.4	0.0	-0.1	4.2	4.7	4.8	
9:30:00	36	108	130.0	1.7	200	1.92	1.3	0.1	-0.1	4.6	5.0	5.0	
10:00:00	36	109	119.0	1.7	198	1.99	1.3	0.3	-0.1	4.3	5.2	5.3	
10:30:00	36	104	118.0	1.7	193	1.88	1.5	1.4	-0.1	4.2	4.6	4.7	
11:00:00	37	104	121.0	1.7	201	1.88	1.3	0.1	-0.1	4.1	5.0	5.1	
11:30:00	36	103	114.0	1.7	204	2.06	1	0.1	-0.1	4.3	5.0	5.1	
12:00:00	36	106	116.0	1.6	205	1.94	1.5	0.3	-0.1	3.9	4.9	5.0	
12:30:00	36	107	117.0	1.6	201	1.93	1.4	0.3	0.0	4.2	5.3	5.5	
13:00:00	37	104	112.0	1.6	197	1.88	0.9	0.3	-0.1	4.5	5.4	5.4	
13:30:00	37	104	114.0	1.7	219	1.86	1	0.1	0.0	4.9	5.7	5.8	
14:00:00	36	103	124.0	1.7	184	1.90	1	0.3	-0.1	3.3	5.2	5.2	
15:00:00	37	103	114.0	1.7	209	2.00	1.6	0.2	-0.1	4.4	5.0	5.1	
15:30:00	37	106	117.0	1.7	193	1.90	0.9	0.6	-0.1	3.4	5.6	5.8	
16:00:00	36	107	118.0	1.7	196	1.90	0.8	0.5	-0.1	4.3	5.4	5.5	
16:30:00	36	109	117.0	1.7	194	1.92	1.1	0.3	-0.1	3.5	5.2	5.3	
17:00:00	37	104	122.0	1.7	204	1.95	1.6	0.1	-0.1	4.4	4.7	4.8	
17:30:00	37	103	122.0	1.7	199	1.96	1.1	0.5	-0.1	3.8	5.5	5.7	
18:00:00	35	102	217.0	1.7	192	2.32	1.2	0.1	-0.1	4.6	4.8	5.0	
Average	36.39	105.22	124.39	1.67	199.17	1.95	1.22	0.31	-0.09	4.16	5.12	5.23	
Maximum	37	109	217	1.65	204	2.32	1.6	0.5	-0.1	4.6	5.5	5.7	
Minimum	35	102	117	1.65	192	1.92	1.1	0.1	-0.1	3.5	4.7	4.8	

NOTE: Instrument failure at 14:30:00 reading

6/16/96	Kiln Vacuum In H2O	Kiln Out Degs F	Clone Out Degs F	WEESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
	PI-210	PI-510	PI-512	PI-524	PI-554	PI-502	PI-582	PI-212A	PI-212B	PI-212C	PI-212D	PI-212E	PI-212F
9:00:00	0.35	378.6	322	210	88	91	91	493	682	706	841	866	894
9:30:00	0.35	378.7	320	210	88	96	96	479	653	702	821	862	895
10:00:00	0.37	382.1	331	211	89	101	100	480	663	696	838	861	885
10:30:00	0.41	385	332	210	90	99	98	496	664	687	827	851	886
11:00:00	0.37	381.4	331	211	90	99	99	471	670	697	820	855	891
11:30:00	0.30	386.1	332	211	90	103	105	496	680	701	844	857	883
12:00:00	0.36	388.9	331	211	90	101	101	474	646	702	821	866	901
12:30:00	0.34	393.9	330	212	90	103	104	480	663	688	822	849	879
13:00:00	0.35	393.1	332	212	90	103	105	488	656	692	815	846	864
13:30:00	0.16	392	332	212	90	103	104	503	681	705	850	856	876
14:00:00	0.59	396.5	332	212	90	102	102	480	664	710	838	859	899
15:00:00	0.30	388.6	335	211	90	98	100	472	647	688	837	855	891
15:30:00	0.55	390.3	334	211	90	98	98	486	650	691	843	862	887
16:00:00	0.43	384.5	336	210	90	95	96	472	634	674	823	851	883
16:30:00	0.51	385.5	334	211	90	95	95	492	661	690	819	853	878
17:00:00	0.31	391	333	210	89	93	93	491	664	699	842	861	898
17:30:00	0.39	386.1	333	210	89	92	92	480	651	685	805	856	888
18:00:00	0.54	393.5	331	210	88	88	86	524	681	692	837	854	887
Average	0.39	387.54	331.16	210.81	89.71	97.88	98.06	486.50	661.67	694.72	830.17	856.67	886.94
Maximum	0.54	393.5	333.8	210.5	90.2	95.4	95	524	681	699	842	861	898
Minimum	0.31	385.5	330.6	209.6	88	87.8	86	480	651	685	805	853	878

6/16/96		Ash Temp Degr F	WESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
	TI-811	TI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	AI-526B	FI-528	
9:00:00		576.5	73	27	4	68	78	52	1491	8.2	7.2	2.7
9:30:00		556.5	73	32	5	68	77	53	1481	8	7.2	2.6
10:00:00		557.2	73	36	4	68	75	50	1473	8	7.2	2.5
10:30:00		553.2	74	38	1	68	72	56	1462	8	7.2	2.6
11:00:00		554.5	73	13	2	67	71	59	1454	8	7.2	2.2
11:30:00		541.8	73	24	4	66	72	54	1444	8	7.2	2.6
12:00:00		552.3	73	29	5	64	73	58	1436	8	7.1	2.6
12:30:00		550.0	73	35	5	63	74	50	1426	8	7.2	2.6
13:00:00		540.2	73	2	6	61	74	53	1418	8	7.1	2.6
13:30:00		547.6	74	22	6	60	74	58	1407	8	7.1	2.6
14:00:00		548.7	73	27	3	59	75	54	1399	8	7.1	2.6
15:00:00		563.8	73	14	4	58	75	57	1380	8.1	7.1	3.4
15:30:00		572.6	73	15	4	57	75	57	1369	8.1	7.1	3.5
16:00:00		565.3	73	23	2	56	73	58	1360	8.1	7.1	3.4
16:30:00		563.1	73	26	4	55	73	53	1350	8.1	7.1	3.4
17:00:00		567.2	73	26	1	93	74	50	1341	8.1	7.1	3.5
17:30:00		564.6	73	28	4	96	74	50	1323	8.1	7.1	3.5
18:00:00		562.6	73	37	5	94	75	55	1255	8.1	7.2	3.4
Average		557.65	73.11	25.22	3.83	67.83	74.11	54.28	1403.83	8.05	7.14	2.91
Maximum		567.2	73	37	5	96	75	55	1350	8.1	7.2	3.5
Minimum		562.6	73	26	1	55	73	50	1255	8.1	7.1	3.4

6/17/96	WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
	FI-521	FI-712	FI-714	SI-211	SI-582	WI-110	PI-582	PDI-510	PDI-532	PDI-542	PDI-560	PI-581	PDI-572
16:30:00	46	108	117.0	1.8	218	0.16	1.6	0.4	0.1	4.6	5.3	5.5	0.2
17:00:00	46	104	116.0	1.8	196	2.19	1.5	0.3	0.0	3.8	4.6	4.7	0.1
17:30:00	46	105	182.0	0.6	186	1.95	1.2	0.3	0.0	3.5	4.4	4.5	0.1
18:00:00	46	107	119.0	0.8	186	1.87	1.2	0.6	0.0	3.6	4.7	4.8	0.1
18:30:00	45	104	168.0	0.2	189	1.87	1.2	0.4	0.0	3.7	4.6	4.7	0.1
19:00:00	46	102	199.0	1.7	188	1.92	1.3	0.7	-0.1	3.7	4.6	4.7	0.1
19:30:00	46	106	225.0	1.7	197	1.87	1.6	0.6	-0.1	2.8	4.7	4.9	0.2
20:00:00	46	108	261.0	1.8	181	2.58	0.9	0.4	-0.1	5.3	5.0	5.2	0.2
20:30:00	46	103	228.0	1.6	183	1.61	1.2	0.4	-0.1	2.8	5.1	5.3	0.2
21:00:00	46	102	279.0	1.7	196	1.84	1.8	0.2	-0.1	3.0	5.0	5.1	0.1
21:30:00	46	103	259.0	1.0	202	1.95	1.3	0.3	-0.1	4.4	4.7	4.8	0.1
22:00:00	46	103	224.0	1.8	199	1.91	0.9	0.2	-0.1	4.1	4.9	5.1	0.8
Average	45.92	104.58	198.08	1.37	193.42	1.81	1.31	0.40	-0.05	3.78	4.80	4.94	0.19
Maximum	46	108	279	1.76	218	2.58	1.8	0.7	0.1	5.3	5.3	5.5	0.8
Minimum	45	102	116	0.19	181	0.16	0.9	0.2	-0.1	2.8	4.4	4.5	0.1

6/17/96	Kiln Vacuum In H2O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
	PI-210	PI-510	PI-512	PI-524	PI-554	PI-502	PI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F
16:30:00	0.18	386.4	339	211	90	106	99	480	592	583	765	795	872
17:00:00	0.44	394.3	340	210	90	101	97	488	627	642	800	816	886
17:30:00	0.53	392.8	336	210	89	96	93	488	640	625	770	800	892
18:00:00	0.52	391.5	336	210	89	96	92	497	622	610	761	801	891
18:30:00	0.50	391.1	338	210	89	93	90	500	629	620	783	804	876
19:00:00	0.46	392.4	336	210	88	88	88	488	630	623	778	801	882
19:30:00	0.52	394.5	336	210	88	87	87	503	600	612	790	795	881
20:00:00	0.70	388.9	326	209	88	85	86	508	585	563	732	762	829
20:30:00	0.66	398.5	334	210	88	85	85	528	633	630	810	872	949
21:00:00	0.52	397.6	332	210	88	85	85	491	661	673	817	839	837
21:30:00	0.38	398.5	334	210	88	85	85	508	646	645	800	848	818
22:00:00	0.39	394.3	334	210	87	85	84	493	626	619	753	830	803
Average	0.48	393.40	335.03	210.00	88.62	91.10	89.25	497.67	624.25	620.42	779.92	813.58	868.00
Maximum	0.7	398.5	340.4	211.3	90.2	105.8	99	528	661	673	817	872	949
Minimum	0.18	386.4	326.2	208.6	87.1	85.2	84	480	585	563	732	762	803

6/17/96	Ash Temp Degs F	WEESP Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
16:30:00	550.9	74	26	4	66	73	59	1855	8.2	7.0	5.2
17:00:00	544.8	74	17	5	64	76	53	1847	8.1	7.0	5.0
17:30:00	552.2	74	5	3	61	75	50	1846	8.2	7.1	5.1
18:00:00	560.6	74	12	3	59	74	56	1836	8.1	7.1	5.1
18:30:00	558.0	74	5	5	58	74	49	1816	8.1	7.1	4.9
19:00:00	561.1	73	25	2	57	74	53	1807	8.1	7.1	5.0
19:30:00	547.8	73	36	3	56	76	54	1796	8.1	7.1	5.0
20:00:00	528.8	73	13	2	54	79	53	1788	8.1	7.1	5.2
20:30:00	545.3	73	38	1	53	79	58	1778	8.1	7.1	4.9
21:00:00	566.1	73	28	2	52	78	56	1759	8.1	7.1	4.7
21:30:00	553.0	73	39	2	50	77	50	1751	8.1	7.1	5.0
22:00:00	544.0	73	33	5	49	77	58	1740	8.2	7.1	5.1
Average	551.05	73.42	23.08	3.08	56.58	76.00	54.08	1801.58	8.13	7.08	5.02
Maximum	566.1	74	39	5	66	79	59	1855	8.2	7.1	5.2
Minimum	528.8	73	5	1	49	73	49	1740	8.1	7	4.7

## BCDP Operating Data During the Stack Test on June 18, 1996

6/18/96	WESP Recycle GPM	Kiln Steam Lbs/Hr	WESP Steam Lbs/Hr	Kiln Rotation RPM	ID Fan Speed RPM	Feed Rate Tons	ID Fan Out In H2O	Clone D/P In H2O	Pr Cond D/P In H2O	Scrubber D/P In H2O	ChillCond Out In H2O	ID Fan In H2O	HEME D/P In H2O
	Fl-521	Fl-712	Fl-714	SI-211	SI-582	WI-110	PI-582	PDI-510	PDI-532	PDI-542	PDI-560	PI-581	PDI-572
12:30:00	45	102	408.0	1.4	225	1.91	1.6	0.7	0.0	3.0	5.4	5.6	0.2
13:00:00	46	101	290.0	0.3	202	1.89	1.2	0.2	0.0	3.1	5.8	6.1	0.3
13:30:00	43	104	442.0	1.7	236	2.27	3.1	0.3	0.1	3.5	4.8	5.1	0.3
14:00:00	46	103	113.0	1.8	187	2.14	1.6	0.4	0.1	3.0	5.4	5.6	0.0
14:30:00	41	108	117.0	0.9	201	1.83	0.9	0.6	0.1	5.2	5.5	5.6	0.2
15:00:00	46	107	119.0	0.2	195	1.90	0.9	0.2	0.1	5.6	5.6	5.9	0.3
15:30:00	46	104	138.0	0.3	190	1.92	1.5	0.2	0.1	3.5	5.6	4.6	0.0
16:00:00	45	104	242.0	1.4	232	1.95	2.7	0.0	0.2	4.1	4.4	4.6	1.5
16:30:00	46	103	124.0	1.8	199	1.86	1.7	0.1	0.1	5.5	4.8	5.0	0.2
17:00:00	45	107	228.0	0.7	197	1.96	0.9	0.3	0.1	2.4	5.9	6.0	0.1
17:30:00	46	107	233.0	1.8	205	1.91	0.9	0.4	0.0	2.6	6.6	6.7	0.1
18:00:00	46	107	263.0	1.8	191	1.90	1.8	0.2	0.0	3.2	5.5	4.1	0.0
18:30:00	46	106	300.0	1.5	212	1.87	1	0.3	0.0	3.0	6.1	6.4	0.3
19:00:00	46	107	329.0	1.8	230	1.82	2.6	0.1	0.0	4.9	4.4	4.7	0.3
19:30:00	45	108	337.0	0.4	198	1.98	0.8	0.4	-0.1	2.4	5.9	6.2	0.3
20:00:00	45	103	317.0	0.6	207	1.93	0.8	1.3	-0.1	4.3	6.1	6.2	0.1
20:30:00	46	103	297.0	1.7	197	1.88	0.8	0.3	-0.1	3.2	6.0	6.2	0.1
21:00:00	45	103	343.0	1.7	186	1.93	0.9	0.3	-0.1	3.9	5.5	5.8	0.3
Average	45.22	104.83	257.78	1.20	205.00	1.94	1.43	0.35	0.03	3.69	5.52	5.58	0.26
Maximum	46	108	442	1.76	236	2.27	3.1	1.3	0.2	5.6	6.6	6.7	1.5
Minimum	41	101	113	0.21	186	1.82	0.8	0	-0.1	2.4	4.4	4.1	0

6/18/96	Kiln Vacuum In H2O	Kiln Out Degs F	Clone Out Degs F	WESP Out Degs F	Scrubber Out Degs F	Stack Out Degs F	ID Fan Out Degs F	#1 Bed Temp Degs F	#2 Bed Temp Degs F	#3 Bed Temp Degs F	#4 Bed Temp Degs F	#5 Bed Temp Degs F	#6 Bed Temp Degs F
PI-210	TI-510	TI-512	TI-524	TI-554	TI-502	TI-582	T-212A	T-212B	T-212C	T-212D	T-212E	T-212F	T-212F
12:30:00	0.58	409.4	338	210	90	92	444	613	648	766	821	795	
13:00:00	0.68	407.7	335	210	89	88	470	635	647	778	824	791	
13:30:00	0.24	409.1	336	210	89	95	439	623	641	778	832	796	
14:00:00	0.61	396	332	211	90	93	440	578	581	754	768	755	
14:30:00	0.34	394.5	333	211	89	93	455	586	579	748	743	745	
15:00:00	0.40	402.1	333	209	90	93	475	611	622	772	795	765	
15:30:00	0.55	411.1	342	210	89	95	475	659	652	783	815	780	
16:00:00	0.08	409.9	343	210	90	93	477	671	654	783	819	795	
16:30:00	0.36	412	344	210	90	98	482	654	663	799	837	789	
17:00:00	0.54	410.4	344	210	90	94	477	637	662	775	833	790	
17:30:00	0.42	408.8	342	210	90	92	89	484	643	667	775	826	794
18:00:00	0.55	409.6	338	209	90	91	89	484	652	658	793	830	788
18:30:00	0.40	405.6	340	210	89	90	88	492	646	668	782	838	797
19:00:00	0.05	407.7	342	210	89	88	87	501	659	662	804	829	797
19:30:00	0.54	408	342	210	89	86	87	487	662	675	794	835	796
20:00:00	0.42	403.4	343	210	88	86	475	640	659	779	829	794	
20:30:00	0.54	407.1	344	210	88	85	473	638	652	771	870	797	
21:00:00	0.65	408.1	344	210	88	84	470	640	652	777	856	805	
Average	0.44	406.69	339.71	210.01	89.41	90.82	90.00	472.22	635.94	646.78	778.39	822.22	787.17
Maximum	0.68	412	344.4	210.9	90.4	98.3	96	501	671	675	804	870	805
Minimum	0.05	394.5	331.8	209.3	88	84.2	84	439	578	579	748	743	745

6/18/96	Ash Temp Degs F	WEsp Sump %	Primary Cond %	Scrubber Level In	Polymer Level %	Clarified Water %	Treated Water %	Diesel Tank Gals	pH Adj In pH	pH Adj Out pH	pH Adj Flow GPM
Time		TI-811	LI-524	LI-530	LI-552	LI-610	LI-665	LI-680	LI-750	AI-526A	FI-528
12:30:00	523.7	95	16	2	75	72	55	1424	8.1	7.1	5.0
13:00:00	528.2	73	30	4	77	75	59	1415	8.2	7.1	5.0
13:30:00	528.2	86	40	4	71	78	55	1406	8.1	7.1	3.7
14:00:00	536.2	74	31	4	69	79	50	1398	8.2	7.1	4.1
14:30:00	521.3	73	23	4	69	78	54	1387	8.2	7.0	3.6
15:00:00	520.8	74	37	4	67	78	52	1379	8.2	7.1	4.2
15:30:00	526.3	73	25	4	67	77	52	1369	8.2	7.1	4.3
16:00:00	536.0	73	2	2	68	76	55	1360	8.1	7.1	4.2
16:30:00	547.5	73	34	3	66	74	54	1350	8.2	7.0	4.3
17:00:00	541.0	74	33	5	66	74	51	1341	8.2	7.0	4.3
17:30:00	543.5	73	38	3	67	73	56	1331	8.2	7.1	4.3
18:00:00	541.2	74	34	2	65	73	57	1256	8.2	7.0	4.2
18:30:00	547.1	74	31	2	64	75	56	1248	8.2	7.1	4.4
19:00:00	556.9	74	35	4	62	78	50	1229	8.2	7.1	4.3
19:30:00	553.8	73	19	3	60	78	53	1218	8.2	7.1	4.4
20:00:00	575.8	73	32	2	59	75	51	1210	8.2	7.1	4.3
20:30:00	564.2	73	40	4	59	70	50	1199	8.3	7.1	4.4
21:00:00	562.3	73	18	6	59	64	55	1191	8.3	7.1	4.3
Average	541.89	75.28	28.78	3.44	66.11	74.83	53.61	1317.28	8.19	7.08	4.29
Maximum	575.8	95	40	6	77	79	59	1424	8.3	7.1	5
Minimum	520.8	73	2	2	59	64	50	1191	8.1	7	3.6

Data Logged Manually During the BCPD Operations

Date	5/5/96	5/6/96	5/7/96	5/7/96	6/11/96	6/12/96	6/13/96	6/18/96	6/24/96	6/27/96	7/19/96
Time	0945	0830	0640	1330	1400	0710	1200	1030	1015	1500	0730
Boiler Pressure, psi	13			13.5		16	16		13	11	
CTW pressure, psi	40	40	40	40	40	40	40	40	40	40	38
<b>WESP</b>											
WESP Recirc., psi	26 - 30	28 - 31	28 - 31	28 - 31	30 - 35	26 - 28	45 - 47	32-33	44	35	
AC Amps	4 - 7	5 - 7	4 - 6	4 - 6	5 - 7	5 - 6	5 - 6	6 - 14	5 - 17	5 - 10	2 - 3
AC Volts	105 - 112	100 - 117	110 - 120	110 - 120	112 - 125	100 - 120	100 - 120	76 - 96	79-122	80 - 100	55 - 60
DC Millamps	20 - 30	20 - 30	20 - 30	20 - 30	24 - 34	26 - 36	20 - 40	36 - 54	~50	50 - 100	12 - 14
DC Kilovolts	14 - 18	14 - 17	15 - 20	15 - 20	15 - 18	16 - 18	15 - 18	10 - 14	9 - 13	9 - 12	9 - 12
Conduction Angle											
Spark Interval - sec	5 - 7	3 - 6	4 - 7	6 - 8	6 - 10	5 - 7	1 - 9	1 - 6	1 - 10	1 - 7	
Gas in Scrubber	Foggy	Foggy	Clear	Clear	Clear	Clear	Clear	Foggy	Foggy	Foggy	
<b>PRIMARY COND.</b>											
CTW in - deg. F	78	78	78	76	79	79	78	79	78	78	78
CTW out - deg. F	88	90	90	85	85	90	91	90	90	90	90
Gas out - deg. F	82	81	80	83	84	81	83	83	82	85	80
<b>HME</b>											
In use (A/B)	B	B	B	B	B	A	A	A	A	A	A
Outlet Temp.	75										
<b>REFRIGERATION UNIT</b>											
Ref Temp deg. F:											
Suction	40		49	35		48	34	34	34	46	Down
Load out	31		31	32		32	32	32	32	32	Down
Load in	33		33	33		33	34	33	34	33	Down
Vapor Coil deg. F											
in	95		79			85	100	94	94	777	Down
out	43		44	46		46	47	47	47	47	Down
coil	36		37	38		37	37	38	38	38	Down

Data Logged Manually During the BCPD Operations

Date	7/22/96	8/9/96	8/11/96	9/6/96	9/9/96	9/20/96	2/13/97	2/26/97	2/26/97	2/27/97
Time	0930	1120	1000	1430	0620	1100	1130	0815	1306	0900
Boiler Pressure, psi	15.5	13						17		1305
CTW pressure, psi	38	40	40	38	38	39	38	38	38	15.5
<b>WESP</b>										
WESP Recirc., psi	33					32		28	37	40
AC Amps	1 - 4	8 - 10	6 - 8	2 - 3	2 - 3	3 - 4	2 - 5	3 - 4	3 - 5	4 - 5
AC Volts	55 - 60	110 - 115	112 - 120	80 - 90	70 - 90	80 - 84	40 - 50	105 - 120	112 - 120	110 - 120
DC Millamps	8 - 18	45 - 50	20 - 30	10 - 14	8 - 12	14 - 18	8 - 16	14 - 18	14 - 18	12 - 16
DC Kilovolts	9 - 13	13 - 15	16 - 18	14 - 16	16 - 17	16 - 17	7 - 9	19 - 21	19 - 21	17 - 20
Conduction Angle								30 - 35	32 - 37	32 - 40
Spark Interval - sec			3 - 8							34 - 40
Gas in Scrubber			Clear	Clear						
<b>PRIMARY COND.</b>										
CTW in - deg. F	78	79	78	78		81	78	75	76	78
CTW out - deg. F	83	90	90							78
Gas out - deg. F	83	82	82	82	82	82	84	84	80	80
<b>HEME</b>										
In use (A/B)										
Outlet Temp.										
<b>REFRIGERATION UNIT</b>										
Ref Temp deg. F:										
Suction										
Load out										
Load in										
Vapor Coil deg. F										
in										
out										
coil										

**APPENDIX D**

**STANDARD OPERATING PROCEDURES (SOP)**

## **APPENDIX D**

## **STANDARD OPERATING PROCEDURES**

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<b><u>SOP No.</u></b>	<b><u>Title</u></b>
001	Lockout/Tagout
002	Decontamination
003	Confined Space Entry
004	Hot Work in Hazardous Locations
005	Primary Condenser
006	Multi-Clone Dust Collectors
007	Johnston Boiler
008	Air Carbon Units
009	Wet Electrostatic Precipitator
010	Loader/Track Loader
011	Loaders - Rubber Tire
012	Heavy Equipment Operations
013	Trackhoe or Excavator
014	Qualifications to Operate Heavy Equipment
015	Refrigeration/Chiller Operation
016	Filter Press Operation
017	Water Carbon
018	Flocculation Tank
019	Particulate Filter and Carbon Bypass - Surge Tank Operation
020	Wastewater Bag Filter Units
021	Clarifier
022	Rotary Kiln Reactor (Calciner)
023	High Efficiency Mist Eliminator (HEME)

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***(continued)***

<b><u>SOP No.</u></b>	<b><u>Title</u></b>
024	Feed Belt Operation
025	Scrubber Operation and Maintenance
026	Eagle Crusher Cleaning
027	Cooling Tower Operation
028	Induced Draft Fan
029	Radial Stacker
030	Spill Notification and Response
031	Off-Gas Bypass Operation
032	Ash Handling Operations
033	Continuous Emissions Monitoring (CEM) System
034	BCDP Restart Approval
035	Feed Chute Cleanout Procedure
036	Wastewater Discharge Sampling
037	Soil and Ash Sampling

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 6, 1995

TITLE: **LOCKOUT / TAGOUT**

PURPOSE: To apply lockout (primary method) devices or tagout (secondary method) devices to each energy isolating device to prevent the unexpected re-energization, start-up, or release of stored energy while servicing or maintenance is being performed on machines or equipment.

HAZARDS IDENTIFIED: Unexpected release of stored energy or the energization of machines or equipment that will cause employee injury.

HAZARD CONTROL MEASURES: Proper training and procedures.

### **DEFINITIONS:**

#### **ENERGY SOURCE**

Any electrical, mechanical, hydraulic, pneumatic, chemical, thermal, pressurized vessel or piping, or any other potential energy source.

#### **LOCKOUT DEVICE**

A device that utilizes a positive means such as a lock to hold the energy isolating device in a safe position and prevents the unexpected energization of the machine or equipment.

#### **PERSONAL LOCK**

A personal lock is marked as belonging to an individual as well as color coded to show the individual's department. Each individual will have the key to his personal lock.

#### **PROCESS LOCK**

A process lock is an additional control beyond each personal lock to ensure no start-up occurs until the whole process is ready to start. Each operator will have access to a key to the process locks.

### **TAGOUT DEVICE**

A prominent warning device such as a tag with a means of attachment which can be securely fastened to an energy isolating device to indicate that the device and the equipment being controlled cannot be operated until the tagout device is removed.

### **LOCKOUT BOOK**

The Lockout Book is a log of all current equipment on which maintenance work is being performed and/or has had a lockout or tagout device attached. This Lockout Book will be kept in the control room. When a gold operations lock is applied, the date, employee's name, equipment name or number, and reason for lockout will be entered in the book. Whenever a gold operations lock is removed, the date and employee's name will be logged.

### **BLINDING AND BLANKING**

Blinding or blanking is an isolation method to prevent liquids or gases from entering a work area. The method utilizes a solid plate spacer inserted between the ends of a broken flange within a piping system. This is the preferred approach in isolating a piping system over that of simply blocking in the valves. The most secure method of blinding is that of attaching a blind flange on the supply side flange of a pipeline, thus, completely isolating the hazard from the work area.

### **BLOCK AND BLEED**

Blocking in (valve closing) and bleeding a piping system is a typical isolation method. This method is simply the blocking of all valves associated with a piping system that may effect the work area, bleeding the pressure off via process drains or by breaking a flange loose and slowly draining or depressurizing liquids/gases from the piping. In relation to completely isolating the system, as blinding and blanking, this method is considered an adequate approach, but due to possible valve failure, is not considered a total safety provision under this procedure. A double block and bleed approach provides a secondary confidence level failure.

### **TAGOOUT**

Tagout is a term referring to the operating practice of attaching cautionary tags to equipment control valves, levers, or switches. These tags serve as safety precautions in two ways. The cautionary tag provides written notification at the valve/switch as to the status/condition of the valve or piece of equipment controlled by the tagged valve as well as who to contact (maintenance/instrumentation/engineering/operations) for additional information. Tagging is not to be considered as a means of securing a piece of equipment for maintenance.

## **RESPONSIBILITY:**

### **GENERAL SUPERINTENDENT**

The General Superintendent has the overall responsibility for compliance with the lockout/tagout procedures. The General Superintendent will maintain a master list of key numbers and the extra key to each personnel lock. In no case will the General Superintendent lend the master key. The General Superintendent or his designee will use the key himself then place the key back in the lock box. If the original key is lost, then the lock and extra key will be destroyed and replaced by new ones.

### **SHIFT SUPERVISOR**

The Shift Supervisor is responsible for verifying that all proper lockout procedures have been followed, including power disconnect operations, appropriate attachment of locks and tags, and proper documentation of these lockout procedures.

### **OPERATOR**

The Operator is responsible for the Lockout Logbook and that all documentation is logged and kept up-to-date. The Operator is also responsible for following proper lockout procedures, including power disconnect operations; appropriate attachment of blinds, chains, locks, and tags; and proper documentation of these lockout procedures.

### **MAINTENANCE - ELECTRICAL AND MECHANICAL**

The Maintenance person is responsible for applying their personal lock to the power source of the equipment that they are working on. This will take place only after operations has applied their lock and verified that equipment is ready to be worked on.

### **ON-SITE HEALTH AND SAFETY COORDINATOR**

The Health and Safety Officer is responsible for verification that all proper site safety precautions are being adhered to, and for compliances with OSHA regulations.

## **SAFETY PROCEDURES:**

### **TRAINING**

Health and Safety will provide training to ensure that employees understand the intent of the Lockout/Tagout procedure and that employees are qualified to implement the procedure.

All employees will receive training in the recognition of hazardous energy sources and the means necessary of energy isolation and control.

All employees will be trained and instructed in the purpose and use of the lock, tag, and try procedure. Instruction will emphasize the idea that attempting to re-energize equipment prior to removal of lockout or tagout devices is prohibited.

Documentation of employee training will be maintained and kept current by the Health and Safety department.

The **Gold** operations lock and tag will be applied by the first individual working on the equipment after the lockout has been recorded in the lockout book. Persons responsible for operation of the equipment and personnel working on the equipment are the only persons authorized to install and remove their locks and tags.

Locks are to be used when a machine or piece of equipment is capable of being locked out. All locks will be individually marked or accompanied by a tag to indicate the name of the employee applying the lockout device.

Multiple locking devices will be used by employee(s) first placing their personal lock(s) and tag(s) on this device followed by the operations department's lock. Where only one lock position remains on the multiple device, a second lockout device will be attached at that position.

Padlocks installed on the multiple device are identifiable by a color code for a department lock color coding assignment.

Department	Color Code
Operations ( process )	Gold
Operations ( personal )	Red
Maintenance ( personal )	Green

The process locks (gold) are all keyed the same and used to lockout equipment. Installation of these locks is recorded in the lockout book. All operations personnel will have a key to these locks. The purpose of personal locks (red-operations, green-maintenance) is to provide additional safety when a person is working or entering a piece of equipment. At this time, their personal lock is added to the multiple locking device along with the gold lock. The personal locks are not logged in the lockout book. The gold lock is always the first one on and the last one off.

All tags will contain the employee name, date of application of lock, equipment name or number, and the reason for lockout. The tag will be attached to the multiple lockout device after being logged in the lockout book.

Acceptable methods for lockout of air or hydraulic energy sources include:

- Locking supply valve closed with a bleeder open on the load (suction) side.
- A tagged blank in the supply line.
- Disconnecting and tagging the supply line.

On any equipment that can start automatically, the local control station shall be switched to the "off" position, locked, and tagged by the operating department. This switch must be turned off before opening the disconnect and remain off until the disconnect is closed.

Locking out 220V or 440V equipment will always be done at the main feed or starter panel. Physical disconnection is always the best approach to safety. (This will be done by Instrument and Electrical Department only).

If it is impossible or impractical to lockout a piece of equipment, the General Superintendent and Health and Safety must approve a method to make the equipment safe before any activities beyond normal operations of the equipment are performed.

#### OPERATING PROCEDURE(S):

The following steps will be adhered to when applying lockout and tagout devices.

The Maintenance employee or others who intend to work on equipment notify the Shift Supervisor and Operator of the need to install a lockout or tagout device. This employee will record his name, date of application of the lock, equipment name or number, and reason for the lockout in the equipment lockout book.

The Operator(s) will shut down the machine or equipment in an orderly manner or as described in the O&M Manual. The valves will be tagged out and blocked. The valves and lines will also be bled or depressured where applicable to assure the equipment is properly safe. The Operator(s) will complete all blinding and blanking of lines where required to service valves or other equipment.

Each person working on the equipment must each place their personal lock on the energy isolating device.

Prior to starting work, the Maintenance employee will contact the Shift Supervisor to confirm that all isolation work by the Operators is complete. Prior to beginning work, the Maintenance employee shall "try" to start (energize) the machine or equipment to verify that isolation has been accomplished.

After servicing or maintenance actions are completed and before the lockout devices are removed, the work area will be inspected to remove all non-essential items. The Operator will notify the Shift Supervisor that the equipment is ready to start, ensure all affected employees that the last lockout device is being removed and machine start-up is being done.

If the job is going to be carried over into later shifts, the out-going Operator(s) will remove their personal locks and the on-coming Operator(s) will place their personal locks on the energy isolating device.

#### LOCKOUT/TAGOUT DEVICE REMOVAL:

Each personal lock will be removed from each energy isolating device by the employee who applied them. Removal of lock and or tags by other than the employee who applied the device will only be permitted under the following three (3) conditions:

- The Shift Supervisor has verified that the employee who applied the lock/tag is not at the plant.
- All reasonable efforts have been made to contact and inform the employee that their lock and/or tag is being removed.
- Approval will be required by the General Superintendent, on-duty Shift Supervisor, and Health and Safety after a thorough inspection of the equipment shows that conditions are safe to remove the lock and or tag.

#### ATTACHMENT:

- LOCKOUT TAGOUT LOG

## LOCKOUT TAGOUT LOG

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 8, 1995

**TITLE:** **DECONTAMINATION**

**PURPOSE:** This operating procedure defines the designated contaminated areas, identifies the corresponding levels of contamination, and generally outlines the operational procedures necessary for decontamination of equipment consistent with the levels and types of contamination encountered throughout the BCDP project site.

**HAZARDS IDENTIFIED:** PCB contamination where significant quantities and concentrations of contaminated materials are present and being processed. Mechanical/equipment hazards.

**HAZARD CONTROL MEASURES:** The proper and thorough decontamination of equipment. Additionally, the appropriate protective gear and equipment required for each designated protection level.

**DEFINITIONS:**

### **REGULATED AREA**

Controlled access is any permanent or temporary hazardous waste Exclusion Zone (EZ) or Contamination Reduction Zone (CRZ).

### **PROTECTION LEVELS**

Levels of personnel protection for the project will be primarily Level D. However, Levels C and B may be used as conditions dictate, i.e., action levels being exceeded.

### **EXCLUSION ZONE (EZ)**

The exclusion zone(s) require sign in/out and the necessary personnel protection equipment.

### **CONTAMINATION REDUCTION ZONE (CRZ) DECONTAMINATION AREAS**

Designated controlled location containing required equipment and facilities for decontamination of personnel, hand tools, and portable and/or mobile equipment.

## **RESPONSIBILITY:**

### **GENERAL SUPERINTENDENT**

Overall responsibility for the operation of the BCDP project including personnel and equipment. As regards this SOP, a direct responsibility for implementation and audit of the use of this procedure. As operations personnel may be required to decontaminate equipment, they are to be familiar with the appropriate procedures including utilization of the required protective gear as well as the use and compliance with the decontamination station equipment.

### **ON-SITE HEALTH AND SAFETY COORDINATOR**

The On-site Health and Safety Coordinator will provide guidance and inspection to verify implementation of site-specific Health and Safety policies. For the purpose of this procedure, he will be responsible for verifying that site safety precautions are met and federal, state, and BCDP regulations are complied with, and will update this SOP as required.

### **SHIFT SUPERVISOR**

Overall responsibility for the operation of their shift including personnel and equipment. As regards this SOP, a direct responsibility for implementation and audit of the use of this procedure. As operations personnel may be required to decontaminate equipment, they are to be familiar with the appropriate procedures including utilization of required protective gear as well as the use and compliance with decontamination station equipment.

## **OPERATING PROCEDURE(S):**

### **REGULATED AREAS; CONTROLLED ACCESS**

Areas of contamination, i.e., EZ and CRZ, are isolated in order to protect the assigned personnel and the general public from the contaminants present and to preclude the transport of contaminants by personnel or equipment from one area to another (cross contamination) or from the site.

All contaminated regulated areas, including temporary isolation due to spills, will be clearly defined by a means suitable to identify the boundaries of the area. This may include special tape, fences, or similar devices as appropriate. Barricades and warning signs shall be posted as necessary to identify the area and the level of protection involved.

### **DECONTAMINATION STATIONS**

The personnel decontamination station (boot wash) consists of small building with suitable equipment and supplies. The personnel decontamination stations are located on the north side of the control room and the south side of the reactor (see Table 2 - PPE, Site Health and Safety Plan).

Personnel conducting equipment decontamination shall be suited in Level C protective clothing as noted in the Site Health and Safety Plan. Level C PPE will be:

- Full face, air purifying respirators with organic vapor cartridge in combination with high efficiency particulate air (HEPA) filter.
- Hooded one piece suit, coated Tyvek or equal, taped at gloves, respirator, and boot covers. Note: regular Tyvek may be used when working with dry material. Undergarments will be provided for use with Tyvek.
- Gloves (Outer) - Chemical resistant nitrile or other impermeable material (leather or canvas outer are used, when working with dry material).
- Gloves (Inner) - Chemical resistant (latex).
- Boots (Outer) - Chemical resistant steel-toed, neoprene boots with or without booties (disposable boot covers when working in or near contaminated soil, debris, or dust make decontamination easier).
- Hard hat.
- Hearing protection (if necessary).

The decontamination stations/pad shall be cleaned at least once a day. All trash will be disposed of in the appropriate manner.

The decontamination stations/pad will be equipped with suitable equipment and supplies to effect a thorough and complete decontamination. This equipment may include water hoses, pressure washers, brushes, cleaning solutions, and steam lances depending on the type, concentration, and extent of contamination and type of equipment requiring decontamination.

## **PERSONAL DECONTAMINATION**

Personal decontamination areas (CRZ) are located on the north side of the control room and the south side of the reactor. These remote facilities will include a boot wash sump, one long handled brush, water hose with a spray nozzle, and a container for holding used PPE. All decontamination areas are to be cleaned each shift.

The Site Health and Safety Plan prescribes the appropriate PPE for use in the EZ and CRZ areas. The normal level of protection is Level D. Level D is used when respiratory and skin contamination is not expected. Decontamination procedures are therefore minimal. At a minimum, boots, gloves, and hands are to be washed and rinsed. Cotton coveralls that are not contaminated are allowed to be worn in the Support Zone areas. Contaminated Tyveks

are to be removed and left in the CRZ. Coveralls will be placed in the laundry room and cleaned by the assigned operator.

PPE clothing such as gloves and Tyvek worn inside the EZ / CRZ areas are not allowed to leave the CRZ. Rubber boots must be decontaminated prior to exiting the EZ/CRZ.

Contaminated protective equipment and gear, such as respirators, hoses, boots, outer protective gear, hand tools, etc., shall not be removed from the contaminated area until they have been thoroughly cleaned, or properly packaged and labeled for disposal. This shall be done inside the CRZ.

Legible and understandable precautionary labels shall be affixed prominently to containers of contaminated scrap, waste, debris, protective gear, and other small equipment for subsequent disposal.

Removal of contaminated soil or dust from equipment by blowing, shaking, or any other means which would disperse contaminants into the air is prohibited.

Decontamination of large equipment shall be done inside secondary containment areas where contaminated water can be contained. After decontamination and before equipment is removed from the area, the OSHSC or designee must inspect the equipment before removal.

The cleaning process will generally consist of spraying all outside surfaces with high pressure water and/or low pressure steam and may also require application of a cleaning solution. Spraying will proceed from the top to the bottom with each surface being cleaned to remove all visible mud, sludge, and particulates and rinsed until visibly free of contamination. Careful attention shall be made to all areas that have come in contact with contaminated materials. Pumps will be flushed internally with clean water, drained, and the inlet and outlet covered prior to external decontamination. Heavy equipment, such as front end loaders, trucks, bobcats, and cranes, will undergo a similar process when they are moved from the contaminated area. Upon completion of the decontamination of the equipment, the area shall be washed and decontaminated.

Final decontamination of equipment for removal from the BCDP site would consist of basic decontamination as outlined in previous instructions followed by additional steps detailed herein.

Disassemble or expose portions of the item so that surfaces which came in contact with contamination are accessible. Some items may not be obvious such as air cleaners and filters, therefore, special consideration must be made to determine hidden locations of possible contamination. Hermetically sealed components and isolated (sealed) components such as electronics and hydraulics should be left assembled during decontamination.

Flush bearings, etc., with new grease or lubricant. Continue to displace (flush) until new grease appears. Exercise caution when washing surface and components with water/steam spray to avoid forcing water in electronic or electrical parts, lubrication reservoirs, etc.

Finish disassembly of electrical housing covers, etc., after wash/steam cleaning to allow visual inspection. All surfaces will be visually detected for presence of soil or other visually detectable contaminates if found, decontaminate as required until clean.

Modifications to the decontamination plans for equipment may be made as appropriate for particular phases of the work or the concentration of contaminated encountered. Subsequent changes will be reviewed by the responsible supervisor and approved by Health and Safety and the Project Managers. Changes shall be included in the Tailgate Safety Meeting prior to implementation.

No food or beverage shall be present or consumed, nor shall tobacco products be present or used, nor shall cosmetics be present or applied at the decontamination stations.

Generally the isolation and control of contamination and the appropriate decontamination of equipment will be conducted under normal operating procedures without incident. There exists, however, the possibility of an emergency situation due to an equipment failure or an accident resulting in higher levels of contamination than an area is designated for under normal conditions. Should any incident occur, the primary objective shall be to protect and decontaminate exposed personnel. Subsequently, if a spill occurs, the following actions are to implemented:

- Contain the spill to prevent spread of contamination.
- Isolate and identify the spilled material.
- Redesignate the area to the proper level of protection if necessary.
- Conduct decontamination of equipment as appropriate for the level of contamination and the existing conditions.
- The OSHSC shall inspect the area decontaminated and document that adequate decontamination is completed.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 6, 1995

TITLE: **CONFINED SPACE ENTRY**

PURPOSE: To set forth minimum requirements and procedures for the safety and health of employees who enter in, about, and in connection with confined spaces on the BCDP project.

HAZARDS IDENTIFIED: The multiple hazards associated with entering and working in confined spaces are capable of causing bodily injury, illness, and death to the worker. Confined spaces can become unsafe as result of: (1) possible atmospheric contamination by toxic or flammable vapors, or oxygen deficiency; (2) possible physical hazards when agitators other moving parts are located therein; (3) the possibility of liquids, gases, or solids being admitted during occupancy; or (4) physical isolation of employees when in need of rescue.

HAZARD CONTROL MEASURES: This SOP prescribes minimum requirements for safe entry, continued work in, and exit from tanks and other confined spaces; and procedures for preventing employee exposure to dangerous air contamination and/or oxygen deficiency.

### **DEFINITIONS:**

#### **ACCEPTABLE ENTRY CONDITIONS**

Means the conditions that must exist in a permit space to allow entry so that employees involved with a permit-required confined space entry can safely enter into and work within the space.

#### **ATTENDANT**

Means an individual stationed outside one or more permit spaces who monitors the authorized entrants and who performs all attendant's duties assigned in the permit space program.

**AUTHORIZED ENTRANT**

Means an employee who is authorized to enter a permit space.

**BLANKING OR BLINDING**

Means the absolute closure of a pipe, line, or duct with no leakage beyond the plant.

**CONFINED SPACE**

Means a space that is large enough and so configured that an employee can physically enter and perform assigned work and has limited or restricted means for entry or exit (for example, tanks, vessels, silos, storage bins, hoppers, vaults, pits, and excavations are spaces that may have limited means of entry) and is not designed for continuous employee occupancy.

**DOUBLE BLOCK AND BLEED**

Means the closure of a line, duct, or pipe by closing and locking or tagging two in-line valves and by opening and locking or tagging a drain or vent valve in the line between the two closed valves.

**EMERGENCY**

Means any occurrence (including any failure of hazard control or monitoring equipment) or event, internal or external, to the permit space that could endanger entrants.

**ENGULFMENT**

Means the surrounding and effective capture of a person by a liquid or finely divided flowable solid substance that can be aspirated to cause death by filling and plugging the respiratory system or that can exert enough force on the body to cause death by strangulation, constriction, or crushing.

**ENTRY**

Means the action by which a person passes through an opening into a permit-required confined space. Entry includes ensuing work activities in that space and is considered to have occurred as soon as any part of the entrant's body breaks the plane of an opening into the space.

**ENTRY PERMITS (CSEP)**

(Attachment) means the written or printed document that is provided to allow and control entry into a permit space and that contains the information specified in acceptable entry conditions this section.

**HAZARDOUS ATMOSPHERE**

Means an atmosphere that may expose employees to the risk of death, incapacitation, impairment of ability to self-rescue (that is, escape unaided from a permit space), injury, or acute illness from one or more of the following causes:

- Flammable gas, vapor, or mist in excess of 10 percent of its lower explosive limit (LEL).
- Atmospheric oxygen concentration below 20.0 percent or above 23.5 percent.
- Atmospheric concentration of any substance for which a dose or a published exposure guideline is available (Permissible Exposure Limit [PEL] from OSHA, Threshold Limit Value [TLV] from ACGIH, and Recommended Exposure Limits [REL] from NIOSH), and which could result in employee exposure in excess of its dose or permissible exposure limits.
- Any other atmospheric condition that is immediately dangerous to life or health.

### **HOT WORK PERMIT**

Means written authorization to perform hot operations (for example, riveting, welding, cutting, burning, and heating) capable of providing a source of ignition. This is a separate document from the entry permit. Hot work permits are issued by the Shift Supervisor and OSHSC only.

### **IMMEDIATELY DANGEROUS TO LIFE OR HEALTH (IDLH)**

Means any condition that poses an immediately or delayed threat to life or that would cause irreversible adverse health effects or that would interfere with an individual's ability to escape unaided from a permit space. **IT does not allow entry into IDLH conditions.**

### **INERTING**

Means the displacement of the atmosphere in a permit space by a noncombustible gas (such as nitrogen) to such an extent that the resulting atmosphere is combustible.

### **ISOLATION**

Means the process by which a permit space is removed from service and completely protected against the release of energy and material into the space by such means as: blanking or blinding; misaligning or removing sections of lines, pipes, or ducts; a double block bleed system; lockout or tagout of all sources of energy, including hydraulic or electric; blocking or disconnecting all mechanical linkages; or physically restraining moving parts.

### **LINE BREAKING**

Means the intentional opening of a pipe, line, or duct that is or has been carrying flammable, corrosive, or toxic material, an inert gas, or any fluid at a volume, pressure, or temperature capable of causing injury.

### **NON-PERMIT CONFINED SPACE**

Means a confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

**OXYGEN DEFICIENT ATMOSPHERE**

Means an atmosphere containing less than 20.0 percent oxygen by volume.

**OXYGEN-ENRICHED ATMOSPHERE**

Means an atmosphere containing more than 23.5 percent oxygen by volume.

**PERMIT-REQUIRED CONFINED SPACE (PRCS)**

Means a confined space that has one or more of the following characteristics:

- Contains or has a potential to contain a hazardous atmosphere.
- Contains a material that has the potential for engulfing an entrant.
- Has an internal configuration such that an entrant could be trapped or by a floor which slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety or health hazard.

**PROHIBITED CONDITION**

Means any condition in a permitted space that is not allowed by the permit during the period when entry is authorized.

**RESCUE SERVICE**

Means the personnel designated to rescue employees from permit spaces.

**RETRIEVAL SYSTEM**

Means the equipment (including a retrieval line, chest or full body harness, wristlets, if appropriate, and a lifting device or anchor) used for non-entry rescue of persons from permit spaces.

**TESTING**

Means the process by which the hazards that may confront entrants of a permit space are identified and evaluated. Testing includes specifying the tests that are to be performed in the permit spaces.

**RESPONSIBILITY:****PROJECT MANAGER**

The Project Manager is responsible for all safety activities on the BCDP site.

## **GENERAL SUPERINTENDENT**

The General Superintendent is responsible for the operating activities of the BCDP plant as well as providing the interface with the Project Manager as regards with all plant operational concerns.

## **SHIFT SUPERVISOR**

The on-duty Shift Supervisor is the first line manager responsible for activities performed during his shift. The Shift Supervisor is responsible for notifying H&S that a permit-required confined space entry will be made, and for verifying that all proper safety precautions have been performed and verified prior to the start of work requiring the CSEP. The Shift Supervisor's signature is required on all CSEP's issued at the BCDP site.

## **ON-SITE HEALTH AND SAFETY COORDINATOR**

The OSHSC will provide guidance and inspection to verify implementation of site-specific Health and Safety policies. For the purpose of the procedure, he will be responsible for verifying site safety precautions, federal, state, and local health and the CSEP permit programs.

### **OPERATING PROCEDURE(S):**

Confined spaces will be identified with a posted sign which reads "Caution - Confined Space" or other equally effective means to identify each confined space.

Smoking in confined spaces is prohibited.

Hand tools used in confined spaces will be in good repair and selected according to the intended use. Where possible, pneumatic power tools will be used. Non-sparking tools will be used where flammable/combustible material are present.

Compressed gas cylinders, except when used for self-contained breathing apparatus (SCBA), will not be taken into confined spaces. Gas hoses will be removed from the space and the supply turned off at the cylinder valve when personnel exit from the confined area. Only SCBA or National Institute for Occupational Safety and Health (NIOSH) approved airline respirators equipped with a 5-minute emergency air supply (egress) bottle will be used.

For entrance and egress, a ladder is required in all confined spaces that are deeper than four feet. The ladder will be secured and will not be removed until all employees have exited the space.

Where personnel are working above open spaces or above equipment that may potentially be dangerous if tools or personnel contact that equipment, scaffolding and/or wood planking will be installed inside the chamber to provide a secure surface for working inside the confined space.

Vehicles will not be left running near confined space work or near the air-moving equipment being used for confined space ventilation.

No deviations from confined space entry procedures will be permitted without the prior approval of the OSHSC.

#### INSPECTION AND TESTS:

- A. The Shift Supervisor shall determine the product which the confined space previously contained, as well as the indicated amount of sludge, residual product, or other contaminants within, and the physical condition of the confined space itself.
- B. The OSHSC and the Shift Supervisor shall make a survey of the surrounding area, including atmospheric testing if appropriate, to determine whether it is safe to enter the area to perform cleaning operations.
- C. Entry into a confined space is prohibited until initial testing of the atmosphere has been completed from the outside. Tests performed may include those for oxygen content, flammability, and toxic contaminants. Additional testing shall be selected and performed to the satisfaction of the OSHSC, based on consultation and recommendations of the Shift Supervisor. Such additional tests shall be made in locations which will be representative of the worst-case conditions that might be anticipated. All tests shall be repeated as often as necessary to provide safety since changing conditions can result in changing atmospheric concentrations. Testing instruments shall conform to applicable maintenance and periodic calibration practices.
- D. All test results shall be recorded on the confined space entry permit. This form shall be clearly posted on the vessel as near as possible to the point where employees will enter the confined space. After job completion, the form is to be retained indefinitely. Permits will be reviewed at least annually to determine if changes to the confined space program are warranted.
- E. All entry permits are valid for a maximum of one (1) work shift, and shall be canceled by the entry supervisor when the shift ends, confined space operations are complete, or whenever a prohibited condition arises in or near the space.

- F. Entry into a confined space for any type of work is prohibited when tests indicate the concentration of flammable gases in the atmosphere is greater than 10 percent of the lower explosive limit (LEL).
- G. Entry into a confined space for any type of work is prohibited when tests indicate the concentration of oxygen to be less than 20.0 percent or greater than 23.5 percent.
- H. Entry into a confined space containing toxic contaminants in concentrations at or above the threshold limit value (TLV) or permissible exposure limit (PEL) shall be permitted only when personal protective equipment is appropriate for the specific contaminants and is provided to all affected employees, based on recommendations of the OSHSC.
- I. The confined space shall be tested as often as necessary to ensure the safety of employees, and whenever conditions in the confined space change, such as temporary stoppage of mechanical ventilation, agitation of tank product by workers, increase in ambient temperature, etc.
- J. The Shift Supervisor shall take positive steps to ensure that employees are protected from other physical hazards, which would include, but are not limited to the following:
- Discharge of steam, high-pressure air, water, or oil into the confined space, or against personnel working outside.
  - Structural failure of the tank shell, roof, roof support members, swing line cables, or other tank members.
  - Tools or other objects dropping from overhead.
  - Falls through or from the roof, or from scaffolds, stairs, or ladders.
  - Tripping over hoses, pipes, tools, or equipment.
  - Slipping on wet, oily surfaces or colliding with objects in inadequately lighted interiors.
  - Insufficient or faulty personal protective equipment.
  - Insufficient or faulty operations equipment and tools.
  - Noise in excess of acceptable levels.
  - Temperature extremes which may require additional protection or shorter work periods.

## ISOLATION:

1. Depressurize the confined space.
2. Prevent accidental introduction into the confined space of hazardous materials through interconnecting equipment such as piping, ducts, vents, drains, or other means.
3. De-energize, lockout, and tagout machinery, mixers, agitators, or other equipment containing moving parts that are in a confined space. Before a method of isolation is selected, the Shift Supervisor shall consider the hazards that may exist or develop from temperature, pressure, flammability, or toxicity of the material in the piping, including reactions with cleaning or purging agents.

## DETAIL:

Before employees are permitted to enter a confined space, the confined space shall be isolated to preclude the entry of hazardous materials by one or more of the following methods:

- A. Removing a valve, spool piece, or expansion joint in piping to, and as close as possible to, the confined space, and blanking or capping the open end of the pipe leading to the confined space.
- B. Inserting a suitable full-pressure blank in piping between the flanges nearest to the confined space.
- C. Closing, locking, and tagging at least two valves in the piping leading to the confined space, and locking or tagging open a drain valve between the two closed valves. The drain valve shall be open to the atmosphere and shall be checked to ensure that it is not plugged. In all cases, blanks or caps shall be of a material that is compatible with the liquid, vapor, or gas with which they are in contact. The material shall also have sufficient strength to withstand the maximum operating pressure, including surges, which can be built up in the piping.
- D. In addition, all electrical and mechanical devices within or attached to the confined space shall be disconnected, or locked, and tagged to prevent accidental movement or energizing of such systems. All employees who will be working in the confined space shall be jobsite trained during pre-entry safety meetings.

## VENTILATION:

- A. Prior to ventilating a confined space, the Shift Supervisor shall take positive steps to ensure that no pyrophoric materials (those that will ignite flammable vapor in the presence of air) are present in the confined space.

Confined spaces shall be mechanically ventilated if necessary to maintain acceptable atmospheric conditions to prevent accumulation of:

1. Flammable in the atmosphere at concentration above 10 percent of LEL.
2. Concentrations of combustible dust.
3. Toxic contaminants in the atmosphere above the TLV/PEL.
4. Toxic and other contaminants having no rated TLV/PEL.
5. Oxygen enriched or deficient atmosphere (<20.0 percent / >23.5 percent O²).

- B. Oxygen shall not be used to power air-driven ventilators.
- C. The Shift Supervisor shall check periodically to ensure that contaminated air from a confined space is exhausted to a location where it presents no hazard.
- D. Whenever possible, air movers shall be used with ducting to increase the efficiency of ventilation in the confined space and to prevent recirculation of contaminated air due to maximized efficiency (i.e., all in the exhaust mode or all in the supply mode).

## EMPLOYEE TRAINING AND INDOCTRINATION:

- A. Entrants/Attendants assigned to work in confined spaces shall have complete formal classroom and practical training which shall include, but is not limited to, the following:
1. Types of confined spaces associated with BCDP activity.
  2. Chemical and physical hazards involved.
  3. Safe work practices and techniques.
  4. Testing requirements, evaluation, and test methods.
  5. Safety equipment, to include:
    - a. Respiratory protective devices.
    - b. Protective clothing and other protection such as harnesses, lifelines, eye protection, power cords, and connectors.

- B. Pre-Entry Safety Meetings detailing specific hazards of the work to be performed and safety precautions and procedures specific for the job shall be conducted by the OSHSC before the initial entry is made, this includes subsequent shifts, and shall be documented in writing.
- C. Personnel shall be retrained for the subject areas listed in Employee Training and Indoctrination at least annually. Proof of training and retraining shall be fully documented in writing. Records shall be maintained by the OSHSC.
- D. The forenamed training shall be complemented with effective, on-going on-the-job training and one-on-one instruction, as part of standard employee supervision, and to the extent necessary to assure compliance with this directive, 29 CFR 1910.146, other BCDP operations policies and procedures, and good health and safety practices.
- E. Rescue Service Personnel: Personnel assigned to provide emergency entry and rescue services shall be trained annually in the proper use of personal protective and rescue equipment. Such training shall include a simulated rescue exercise. All rescue personnel shall have current training and certification for first-aid and CPR.
- F. Retention of Inspection and Test Logs - A copy of all Entry Permits and other documents related directly to the PRCS entry (e.g., hot work permits, etc.) shall be forwarded to the H&S department.
- G. Confine Space Entry Program Review - Annually in January, the OSHSC shall review all entry permits for incidents or problems occurring during entry. Incidents or problems include injuries, accidents, unauthorized entries, or any other event potentially indicating that improvements can be made in the confined space entry program. After review with appropriate operations personnel, recommendations for program revision shall be forwarded to the Health and Safety office for review.

#### ILLUMINATION:

When temporary lighting is used in confined spaces, the following requirements shall be met:

- A. All lighting shall be approved for use in Class I, Division I, Groups A, B, C, and D atmospheres.
- B. Extension cords used for temporary lighting shall be equipped with connections or switches approved for hazardous locations.
- C. Temporary lighting shall be equipped with adequate guards to prevent accidental contact with the bulb.

- D. The lighting shall not be suspended by the electrical cords, unless they are designed for this method of suspension.
- E. Electric cords shall be kept clear of working spaces and walkways or other locations in which they may be exposed to damage.
- F. Temporary lighting and electric cords shall be inspected regularly for signs of damage to insulation and wiring.
- G. Ground Fault Circuit Interrupter (GFCI) protection shall be used for all electrical equipment.

#### PERSONAL PROTECTIVE DEVICES:

When the atmosphere of the confined space to be entered is found to contain contaminants which require supplied air and the concentration cannot be reduced by mechanical ventilation, the following requirements shall be met:

Employees entering the confined space shall be equipped with positive pressure air-supplied respirators using certified Grade D breathing air.

Employees entering the confined space shall be equipped with body harness and lifelines as follows:

1. A chest harness may be used for side entry (opening not greater than 3.5 feet from ground level) where there is no vertical free fall hazard. A quick release catch, which permits escape in case of line fouling, shall be used.
2. When entry must be made through a top opening or side greater than 3.5 feet high, the harness shall be a full-body parachute type that will suspend a person in an upright position. A man-rated hoisting device shall be provided for lifting employees out of the space.

At least one employee shall act as attendant on the outside of the confine space ready to give assistance in case of an emergency. The employee shall have an approved, maintained, self-contained breathing apparatus ready for donning. The attendant shall have no other duties that would interfere with his ability to monitor the confined space.

All employees, including the attendant, shall use applicable protective equipment, such as head and eye protection, gloves, boots, and impervious clothing as required by the nature of the residues to be removed and atmospheric contaminants.

When the atmosphere of the confined space to be entered is found to contain contaminations at concentrations above their respective TLV/PEL and the concentration cannot be reduced by mechanical ventilation, the following requirement shall be met:

- Employees entering the confined space shall be equipped with approved air-purifying cartridge or canister respirators with appropriate cartridges or canister, as required by the nature of the residues to be removed and atmospheric contaminants.

When monitoring of the atmosphere of the confined space shows no reading above background, no special modification of the work procedure should be necessary, except as indicated below:

- Nature of the residue and the proposed cleaning process, such as mechanical cleaning of the tank surfaces, may require the use of air-purifying respirator, head and eye protection, gloves, boots, and impervious clothing.
- Continue periodic monitoring and compare with OSHSC guidelines.
- Other physical stresses such as temperature extremes and excessive noise may require the use of specialized safety equipment in any confined space.

#### CONFINED SPACE - RESCUE:

- A. Attendants shall be used for all entries. **They shall have been trained and drilled in rescue procedures.**
- B. Attendants shall be familiar with pertinent types of atmospheric testing, respiratory protection, rescue procedures, and the proper use of safety and rescue equipment.
- C. Rescuers shall be instructed not to enter a confined space unless others are notified and standing by in case additional help is required.
- D. Tanks, vessels, or other confined spaces with both side and top openings shall be entered from side openings when practical. A chest harness may be used for side entry (not greater than 3.5 feet from ground level) where there is no vertical free fall hazard. A quick-release catch, which permits escape in case of life line fouling, shall be used.

- E. When entry must be made through a top opening, the following requirements shall also apply:
- The safety belt shall be of the parachute harness type (Class III, full body) that suspends a person in any upright position.
  - A man-rated hoisting device shall be provided for lifting employees out of the space where the confined space is greater than 3.5 feet vertical.
- F. Emergency phone numbers shall be posted at the job site (control room near phone).
- G. An accident/incident report will be completed when appropriate.
- H. The on-base Fire Department shall be notified prior to entry, and communication capabilities arranged to summon rescue personnel if needed.

**ATTENDANT:**

Shall be an individual physically capable of rescuing by use of hoist, lifeline and harness, or entry into a confined space and who has current training in;

- A. Cardiopulmonary resuscitation (CPR).
- B. First-aid.
- C. Air-supplied respiratory protective equipment.
- D. Self-contained supplied-air respiratory protective equipment.

**DUTIES:**

1. At least one employee shall stand by on the outside of the confined space ready to give assistance in case of an emergency.
2. When conditions become immediately dangerous to life or health, the confined space shall be evacuated.
3. The employee shall have an approved, maintained, self-contained respiratory protective device outside of the carrying case, ready for work inside the confined space, the standby shall wear the same.
4. If a lifeline and harness are required for work inside the confined space, the standby shall wear the same.

5. An effective means of communication between employees inside a confined space and a standby employee shall be provided and used whenever atmospheric conditions of the confined space require the use of air-supplied respiratory protective equipment, lifelines and harnesses, or whenever employees inside a confined space are out of sight of the standby employee(s). All affected employees shall be trained in the use of such communication system and system shall be tested before each use to confirm its effective operation.
  6. Prior to the worker entry into the confined space, the attendant shall be determined and the location of the nearest:
    - A. Fire alarm.
    - B. Phone.
    - C. Fire extinguisher.
    - D. Eyewash and safety shower (test shall be performed by the standby to be sure the equipment is in proper working order).
  7. The attendant(s) will enter the vessel only after alerting at least one additional employee outside the confined space of the existence of an emergency and of the attendant's intent to enter the confined space, and only in case of emergency such as:
    - A. A worker inside suffers an injury.
    - B. A worker inside indicates breathing difficulties.
- Note: The attendant must meet the training/qualification of a rescuer and be relieved by a qualified attendant.
8. The attendant shall call the worker(s) out of the vessel:
    - A. If the attendant has to leave for any reason.
    - B. If an emergency signal or alarm is sounded.
    - C. If the attendant detects or suspects presence of any harmful substance.

ATTACHMENT:

- ENTRY PERMIT FOR PERMIT-REQUIRED CONFINED SPACE



**ENTRY PERMIT  
PERMIT-REQUIRED CONFINED SPACE (PRCS)**

Division/Location _____ Job No. _____

Customer _____ Address _____

Location of Job _____ Identity of PRCS _____

Describe Hazards of PRCS (Chemical, Physical) _____

Chemical Introduced Into Space _____

Purpose This Permit Authorized _____

<b>CHECKLIST</b>	YES	DOES NOT APPLY	<b>PERSONAL PROTECTIVE EQUIPMENT (Circle)</b>
All lines leading to and from confined space have been blinded or disconnected			<b>EYE/FACE</b> Chemical Goggles Face Shield Safety Glasses
Electrical service disconnected or locked out			<b>EXTREMITIES</b> Hard Hat Gloves (Material _____) Hoods Boots (Material _____) Booties
All grounding and bonding cables in place			<b>BODY</b> Suit (Level _____, Material _____)
All lighting, fittings, power equipment, and extension cords are explosion-proof			<b>RESPIRATORY</b> SCBA Air Line Egress System Air Purifying (Cartridge _____) Powered Air Purifying (Cartridge _____)
Ground Fault Circuit Indicator (GFCI) checked and functioning			<b>OTHER</b> Hearing Protection Harness & Lifeline Chest or Parachute
All ignition sources have been isolated			<b>RESCUE EQUIPMENT</b> Mechanical Extraction Device First Aid Kit SCBA Other (Specify) _____
All respiratory equipment and alarms checked and functional			<b>NON-IT RESCUE TEAM</b> Instructions to Summon Rescue _____
All safety harnesses and life lines checked			<b>COMMUNICATION</b> Lifeline "Tug" Signals (See HASP) Air Powered Horn Signals (See HASP) Other _____ _____
All required PPE checked and in use			_____
All entrants are confined space trained			_____
All entrants are trained in the use, care, and limitations of respirators and PPE			_____
Attendant trained in emergency procedures			_____
Attendant(s) trained in rescue procedures			_____
Outside rescue service will be used and they have been notified of this entry			_____
Appropriate rescue equipment available and checked			_____
Ventilation system in use and effective			_____
Entrant(s) can achieve a gas-tight seal with respirator			_____
Entrant(s) are not wearing contact lenses			_____
All tests have been completed and indicate that entrance requirements have been met			_____
Appropriate warning signs have been posted and unauthorized personnel have been excluded from the PRCS and area			_____
<b>IF THE ANSWER TO ANY OF THE ABOVE QUESTIONS IS NO, ENTRY IS NOT PERMITTED.</b>			_____
<b>OTHER PERMITS ISSUED FOR WORK IN PRCS:</b>			_____
<b>OTHER HAZARD CONTROL PROCEDURES OR INSTRUCTIONS:</b>			_____
			_____

**TEST DATA**  
*Oxygen, Flammability and Toxic Contaminants*

Time	Percent Oxygen	Percent LEL	PEG	PEG	PEG	PEG	PEG	Initials	Comments

**AUTHORIZED ENTRANTS**


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**AUTHORIZED ATTENDANTS**


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**RESCUE PERSONNEL**


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**Diagram the confined space, indicate location of manways and ventilators. Indicate location(s) where tests conducted.**

) ( - Manway

oo - Ventilator

X - Test Location

**ACCEPTABLE ENTRY CONDITIONS**

- 1) Entry Permit Completely Filled Out
- 2) Oxygen between 20-23.5%
- 3) Combustible Gases Below 10% LEL
- 4) Permissible Levels of Toxic Gases (List)

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**PRCS SAFE FOR ENTRY**

DATE/TIME ____ / ____ NAME ENTRY SUPERVISOR _____ SIGNATURE _____

CURRENT ENTRY SUPERVISOR (IF DIFFERENT) _____

ENTRY PERMIT EXPIRES DATE/TIME ____ / ____ (No longer than 1 shift)

**ENTRY PERMIT CANCELLED**

DATE/TIME ____ / ____ SIGNATURE _____

REASON (✓) ____ Work Complete ____ Authorized Conditions not met ____ Incident ____

**DESCRIBE PROBLEMS DURING ENTRY AND RESOLUTION**


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**RECLASSIFICATION TO NON-PERMIT-REQUIRED CONFINED SPACE**

Describe hazard removal methods, without use of ventilation. _____

TESTING VERIFICATION SHOWN AT TIME _____ ON TEST DATA CHART ABOVE.

DATE/TIME ____ / ____ ENTRY SUPERVISOR SIGNATURE _____

REVIEWED BY _____ DATE _____

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 6, 1995

**TITLE:** **HOT WORK IN HAZARDOUS LOCATIONS**

**PURPOSE:** To prescribe workplace health and safety procedures for welding, cutting, and other hot work in hazardous locations.

**HAZARDS IDENTIFIED:** All operations which process, handle, or are otherwise exposed to combustible or flammable liquids, vapors, gases, and solids are subject to the provisions of this directive.

**HAZARD CONTROL MEASURES:** Training to policies and procedures which can be used to reduce the potential fire hazards of hot work.

### **DEFINITIONS:**

#### **ATMOSPHERE**

Refers to the concentrations of gases, vapors, mist, fumes, and dusts within a confined space.

#### **CONFINED SPACE**

Normally considered to be enclosures having limited means for entry and exit, by reason of location, size, or number of openings; and unfavorable natural ventilation which could contain or produce dangerous concentrations of air contaminants, flammable or explosive atmospheres, and/or oxygen deficiency. Confined spaces include, but are not limited to, storage tanks, compartments of ships, process vessels, pits, silos, vats, degreasers, reaction vessels, boilers, ventilation and exhaust ducts, sewers, tunnels, underground utility vaults, bins, tubs, tank trucks, and pipelines.

#### **CONTAMINANT**

Any organic or inorganic substance, dust, fume, mist, vapor, or gas which can be harmful or hazardous to human beings.

**HOT WORK**

Any work involving burning, welding, riveting, or similar fire producing operations, as well as work which produces a source of ignition, such as drilling, abrasive blasting, and space heating.

**IGNITION SOURCE**

Refers to a heat source of sufficient energy to cause ignition of flammable vapors. The most commonly encountered categories of ignition sources in industry are open flames, hot surfaces, and electrical or frictional sparks.

**INERTING**

Displacement of the atmosphere by a nonreactive gas (such as nitrogen or carbon dioxide) to such an extent that the resulting atmosphere is noncombustible.

**ISOLATION**

A process whereby the confined space is removed from service and completely protected against the inadvertent release of materials by the following means: inserting a suitable full-pressure blank (skillet type metal blank between flanges) in all lines, misaligning sections of lines and pipes, or valves chain lockout of lines and pipes; and lockout of all sources of electrical power and blocking or disconnecting all mechanical linkages.

**LEAD HAZARD**

Refers to the potential for exposure to organic (tetraethyl) lead in tanks which have been used for leaded petroleum products. Since these tanks will contain residual lead of varying concentrations, they must be regarded as dangerous to the extent that respiratory (fresh-air gear) and whole body skin protection must be used throughout the cleaning process. These tanks must not be considered lead-free until proven so by lead-in-air analysis. Specific requirements for entry into confined spaces which contain or have contained leaded products are prescribed in IT PRO 9531.3, Confined Spaces, Leaded Product.

**LEL (LOWER EXPLOSIVE LIMIT)**

The minimum concentration of a combustible gas or vapor in air (usually expressed in percent by volume at sea level), which will ignite if an ignition source is present.

**OXYGEN DEFICIENCY**

Refers to an atmosphere with a partial pressure of oxygen of less than 132 mm Hg. Normal air contains approximately 21 percent oxygen. For the purpose of this directive, any atmosphere containing less than 20 percent oxygen is considered immediately dangerous to life and health (IDLH). No work will be performed in an atmosphere containing less than 20 percent oxygen.

## **PURGING**

The method by which gases, vapors, or other airborne impurities are displaced from a confined space. This may involve such measures as mechanical ventilation, steam ventilation, or introducing another gas such as nitrogen or carbon dioxide to control flammable vapors.

## **QUALIFIED PERSON**

A person designated by the employer, in writing, as capable (by education and/or specialize training) of anticipating, recognizing, and evaluating employee exposure to hazardous substances or other unsafe conditions.

## **OPERATING PROCEDURE(S):**

### **MANAGEMENT RESPONSIBILITIES**

- A. Based on fire potentials, area management shall establish areas for welding, cutting, and other hot work on its property.
- B. Area management shall designate an individual responsible for authorizing welding, cutting, and other hot work in areas not specifically designed or approved for such operations. The individual shall be aware of the fire hazards involved and be familiar with the provisions of this directive, and may delegate this responsibility to **qualified persons** as necessary.
- C. Area management shall ensure that only approved apparatus, such as torches, manifolds, regulators, or pressure reducing valves, and acetylene generators be used by IT Corporation employees and contractor personnel.
- D. Area management shall ensure that cutters or welders and their supervisors are properly trained in the safe operation of their equipment, the safe use of the process, and emergency procedures in the event of a fire.
- E. Area management shall select only those contractors who have suitably trained personnel to perform welding, cutting, and other hot work on IT Corporation property.
- F. Area management shall ensure that all contractors have been advised about specified hot work areas, and hazardous locations where special procedures for hot work are necessary.

## **FIRE PREVENTION PRECAUTIONS**

- A. Cutting, welding, or other hot work shall be permitted only in areas that have been made firesafe.
- B. Within the confines of an operating plant, tank farm, or building, cutting and welding shall be done in either:
  - 1. A specific area designed or approved for such work, such as a maintenance shop or a detached outside location which shall be of noncombustible or fire-resistive construction, essentially free of combustible and flammable essentially contents, and suitably segregated from adjacent areas.
  - 2. When work cannot be moved, remove or protect combustibles from ignition sources.
- C. Cutting or welding shall NOT be permitted in the following situations:
  - 1. In areas not authorized by management.
  - 2. In the presence of an explosive atmosphere (mixtures of flammable gases, vapor, liquids, or dust with air), or where explosive atmospheres may develop.
  - 3. In any area where combustible gas indicator readings are in excess of 10 percent of the lower explosive limit.
  - 4. On storage or process vessels or lines in service which contain flammable or combustible liquids, gases, vapors, or solids.

## **PREPARATION AND PERMITS FOR HOT WORK**

Before any welding, cutting, or hot work is permitted, the area shall be inspected by a **qualified person** to ensure that the following requirements have been met:

- Cutting and welding equipment to be used shall be in safe operating condition and in good repair.
- Where practical, all combustible material shall be relocated at least 35 feet horizontally from the work site. Where relocation is impractical, combustibles shall be protected with flame-proofed covers or otherwise shielded.

- Openings or cracks in walls, floors, or ducts within 35 feet of the site shall be tightly covered to prevent the passage of sparks to adjacent areas.
- Where cutting or welding is to be done near walls, partitions, ceilings, or roofs of combustible construction, fire-resistant shields or guards shall be provided to prevent ignition.
- Fully charged and operable fire extinguisher, appropriate for the type of possible fire, shall be available at the work area. Where fire hose-lines are available, they shall be required whenever hot work is performed in hazardous locations.
- Fire watchers shall be required whenever hot work is performed in hazardous locations.
- Combustible gas indicator readings shall be taken to ensure that the work area is free of combustible gases and vapors.
- The work area is free of toxic contaminants at concentrations in excess of established threshold limit valves, or all personnel who will work in the area have been provided respiratory protective devices and protective apparel appropriate for the degree of exposure. In the case of chlorinated hydrocarbons, there can be no contamination at any concentration due to the danger of generating phosgene.
- If hot work requires entry into a confined space, as defined in the above, all provisions of the confined space SOP will be followed.
- When hot work is to be performed on tanks or other vessels that contain or have contained flammable or combustible liquids, the vessel shall be properly isolated, purged, and cleaned, as appropriate, to reduce the concentrations of flammable and toxic air contaminants to safe levels.
- When hot work is to be performed on tanks or other vessels that contain or have contained leaded products, and represent a lead hazard, all provisions of ITC PRO 9531.3, Confined Spaces, Leaded Product, shall be met, and only after consultation with an IT Corporation Occupational Safety and Health Department representative shall hot work be authorized.
- When hot work is to be performed on the bottoms of tanks or other vessels that are not supported above grade, special procedures shall be followed due to the possible entrapment of flammable liquids or vapors beneath the tank. For vessels that have at one time contained flammable materials, refer to "Preparing Tank Bottoms for Hot Work," Petroleum Safety Data 2207, American Petroleum Institute. Work shall be performed on stationary tank bottoms only when both the

IT qualified person and the contractor personnel have become familiar with this reference and the contractor personnel shall follow the outlined procedures.

## **HOT WORK PERMITS**

- A. When the qualified person is satisfied that all the requirements of the above section have been met, the Hot Work Permit, ITC FORM 9571-1, shall be completed, reviewed with personnel who will perform the hot work, and posted near the jobsite.
- B. The hot work permit is good only for the date issued, and is valid only for the twelve-hour shift for which it is issued.
- C. If at any time during the hot work operation a change in conditions at the work site is suspected, such as release of flammable gases or vapors in the work area, work shall be stopped immediately and the hot work shall be completed after inspections and tests have been performed by a qualified person.
- D. No erasures or changes of dates on hot work permits shall be permitted.
- E. When two or more departments or operating divisions have equipment in an area in which a hot work permit is needed, the department or division most closely associated with the hot work shall secure whatever clearance is needed from the other departments or divisions.

## **SPECIAL PERMITS**

In addition to regular hot work permits, such as those for welding and cutting, it may be necessary, based on the potential fire hazard, to require the use of special hot work permits for particular sources of ignition used in hazardous locations.

The following activities and types of equipment are among potential sources of ignition for which hot work permits may be required:

- Torches and other open flames.
- Hot riveting.
- Hot forging.
- Salamanders.
- Combustion engines.
- Portable electric tools.
- Grinding.
- Polishing.
- Drilling.

- Chipping.
- Soldering.
- Sandblasting.
- Freeing seized bearings.
- Portable propane or electrical heaters.
- Hot plates.
- Discharging photographic flash bulbs.

ATTACHMENTS:

- HOT WORK PERMIT

# HOT WORK PERMIT

Operating Area _____ Good for this date only _____ 19_____

specific vessel or equipment _____

Work to be done _____

## TESTS

STATE EXACT LOCATION OF TEST	TIME	PERCENT LOWER EXPLOSION LIMIT		PERCENT OXYGEN	OTHERS		INITIAL

## CHECK LIST

Operations/plant personnel have been informed of work to be performed _____

tanks/lines/valves are disconnected, blinded, or locked out. _____

Equipment and all attached piping has been cleaned and purged with:  
Check blank) Water _____ Steam _____ Inert gas _____ Air _____

Electrical service has been locked out and tagged. _____

Grounding/bonding wire in place. _____

Around equipment and operations are safe for hot work. _____

Open vessels or lines within 35 feet of hot work area. _____

Combustible items within 35 feet of hot work area or covered with wetted tarpaulins. _____

A Watch has been provided by Contractor. _____

Flammable gases greater than 10% LEL in hot work area. _____

Requirements of ITC PRO 9531 for Confined Space Entry have been met and Form 9531-1 has been completed and posted. _____

Vessel contains leaded product, all requirements of ITC PRO 9531.3 have been met. _____

Initial Instructions: _____

Entered by: _____ Name Printed _____ Signature _____ Date _____

Manager _____

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **PRIMARY CONDENSER**

PURPOSE: To cool, condense, and remove water and hydrocarbon vapor from the gas stream.

HAZARDS IDENTIFIED: The inlet gas can be over 200°F. Contact with the gas pipe can cause burns. The gas and the condensate carry organics and PCBs.

HAZARD CONTROL MEASURES: Do not touch the inlet piping unless the system is shut down and has cooled. Use protective clothing when exposure to gas or liquid in the unit is possible.

### OPERATING PROCEDURE(S):

1. Check that all bleeds are closed.
2. Verify that the cooling water flows through the condenser.
3. Open air valves to both #1 and #2 pumps.
4. Open discharge valves on both #1 and #2 pumps.
5. Select the primary pump (#1 or #2).
6. If high water alarm is tripped, the backup pump will start and run to help bring down the level. Backup pump will stay on line until the alarm is reset.

### OPERATING LIMITS:

- Inlet Cooling Water < 90°F
- Outlet Gas < 90°F
- Gas Pressure Drop < 2 inches WC Maximum

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **MULTI-CLONE DUST COLLECTORS**

PURPOSE: To remove PCB contaminated dust and particulate from the off-gas stream.

HAZARDS IDENTIFIED: PCB contaminated dust, surface of vessel can be hot to the touch, heaters located under insulation on cone section.

HAZARD CONTROL MEASURES: Make sure all flanges are sealed to prevent dust from escaping the cyclone system. Prevent burns by not touching metal surfaces during operation. Dress in Level C whenever opening the cyclone, either to work on the internals or to change the fines drum.

### OPERATING PROCEDURE(S):

1. Ensure that the cone section heaters are on when the plant is in operation.
2. Check the level of fines drum by tapping the side of the drum or checking the actual weight via the weight scale.
3. Change out the fines drum when the drum is between 80 percent and 95 percent full or the total weight is approximately 600 pounds. Never allow the drum to fill completely as this could plug the cyclone discharge.

### DRUM CHANGEOUT PROCEDURE:

THE CYCLONE DISCHARGE WILL BE BLOCKED OFF DURING THE ACTUAL DRUM CHANGEOUT. THIS CHANGEOUT TIME MUST BE KEPT TO A MINIMUM TO PREVENT FINES FROM BUILDING UP AND PLUGGING THE CYCLONE.

- Use only drums labeled "1A2X/200S" (the 200 refers to maximum loaded drum weight in Kg). These drums are approved by the United Nations for sea transport of hazardous waste.
- Obtain an empty drum and remove the drum lid.
- PPE dress in Level C.
- Close the block valve between the cyclone and the drum.
- Pull the clamp from the fines drum lid and raise it up with the flexhose still connected. Support the lid with the suspension hooks provided.
- Slide a drum lid onto fines drum and remove it from the cyclone.
- Place the empty drum under the cyclone and attach the lid. The connection between the drum and the cyclone must be airtight. The system operates under vacuum, and air leaking into the cyclone in the direction opposite the fines travel will greatly reduce the efficiency of the cyclone.
- Open the block valve between the cyclone and drum.
- Seal the lid on and weigh the fines drum. Label the drum "Cyclone Fines," and record the gross weight, date, and time on the drum. Also record this information in the shift log.

#### CLEANING PROCEDURE:

1. Follow Lockout/Tagout procedure on heaters to cone section.
2. Refer to Decontamination, SOP No. 002, for proper procedures for cleanout.

#### OPERATING LIMITS:

- Pressure Drop            2 to 5 inches WC
- Shell Temperature      > 300°F

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 21, 1995

**TITLE:** **BOILER**

**PURPOSE:** To operate the boiler in a safe manner.

**HAZARDS IDENTIFIED:** Fire or explosion.

**HAZARD CONTROL MEASURES:** All safety devices and shutdown components must be operated and tested as required.

### **OPERATING PROCEDURE(S):**

#### **BOILER BOIL-OUT** (To be done prior to start-up after an extended shutdown)

1. Isolate boiler from piping system.
2. Remove safety valve from boiler.
3. Fill boiler with clean water.
4. Add Tide detergent.
5. Start up boiler.
6. As boiler begins to boil and develop a steady discharge of steam from the safety valve opening, turn boiler off. Drain the boiler.
7. Repeat this process as often as necessary until discharge water is clear.
8. Allow boiler to cool down to normal hot water temperatures.
9. Drain boiler and refill with hot water, until detergent is removed.

10. Re-install the boiler safety valve.
11. Refill with water.

## **WATER SOFTENERS**

1. Fill mineral tank with the proper quantity of resin.
2. Open hard water line to water softener.
3. Add 12 inches of water to brine tank.
4. Put the softener switch into service position.
5. Open the manual inlet and outlet valves.
6. Fill the brine tank with salt.

## **BOILER START-UP**

1. Set the fuel switch to the desired position.
2. Move the burner air slide fuel selector to the corresponding position.
3. Turn the burner operating mode switch to the manual mode.
4. Turn the firing rate control dial to its lowest setting.
5. Turn the burner switch to the "On" position.
6. Check the low fire holding control, minimum setting should be 180°F.
7. Set the burner operating switch to the "Auto" position.

## **BOILER OPERATION**

1. Manually blow down the boiler daily.
2. Use the test kit to check the water quality in the boiler daily.

## **OPERATING LIMITS:**

• Hotwell Temperature	190°F to 210°F
• Hardness	>4 ppm
• Alkalinity	50 ppm Minimum
• Total Dissolved Solids	3500 - 6500 ppm
• pH	9.5 to 11.5

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **AIR CARBON UNITS**

PURPOSE: To remove organic compounds from the gas stream.

HAZARDS IDENTIFIED: Bulk carbon can deplete oxygen from the air.

HAZARD CONTROL MEASURES: Make sure that bulk carbon is handled only in well ventilated areas. If the carbon is in an enclosed space (such as a closed connex), ventilate before entering the area.

### OPERATING PROCEDURE(S):

1. Before system start-up, valve the carbon units so the gas passes through the two units in series.
2. Open the drain valve at the bottom of the units and drain any water from the carbon tanks. Reclose the valves.
3. During operation, the lead carbon units may become saturated with PCBs to the point that they are passing through the first unit into the second unit. If this occurs, the General Superintendent will issue instructions to change out the saturated carbon unit. **NOTE:** Unless such direction is received, do not alter the flow of gas through the carbon.
4. Once a day open the water drain valves on the bottom of the carbon tanks and drain any accumulated water. Normally, there should be no water. If water drains, estimate the amount and record it in the log book.

## CARBON CHANGEOUT PROCEDURE:

In the discussion below, the carbon that the gas first enters will be called the lead (first) carbon, and the carbon that is ducted directly to the vent stack will be called the lagging (second) carbon. This procedure must be performed when it is not raining.

- A. Valve the units so that all gas is passing directly through the lagging carbon and no gas is passing through the lead carbon.
- B. Unbolt and remove the flanged port on top of the lead carbon.
- C. Mark the level of carbon in the vessel on the outside on the vessel. The carbon units are about half full.
- D. Using a drum vacuum cleaner, remove the carbon from the vessel. Use only drums labeled "1A2X/200S." These drums are approved by the United Nations for sea transport of hazardous waste.
- E. While emptying the vessel, take at least a four-ounce sample of carbon from the top, approximate middle, and bottom of the carbon in the vessel. Label these samples "Spent Air Carbon," and record the location, time, and date.
- F. Weigh the filled drum. Label the drum "Spent Air Carbon," and record the gross weight, date, and carbon vessel number (1 or 2) on the drum. Also record this information in the shift log.
- G. Add fresh carbon to the drum to the marked level.
- H. Reattach the loading flange at the marked level.
- I. Change the valves so that the older carbon becomes the lead carbon vessel and the fresh carbon is the lagging carbon.

## OPERATING LIMITS:

- Pressure Drop > 20 inches WC.

NOTE: After experience has been gained with the Continuous Emissions Monitor (CEM), criteria will be added concerning when to change out the carbon.

## **OPERATIONS SOP**

REVISION DATE: SEPTEMBER 15, 1997

TITLE: **WET ELECTROSTATIC PRECIPITATOR**

PURPOSE: The Electrostatic Precipitator or WESP removes particulate by placing a charge on the particle and then collecting the particles on an oppositely charged tube. A water wash is utilized to keep the tubes clean. This wash water is collected and treated in the on-site water treatment plant.

HAZARDS IDENTIFIED: Possible exposure to high voltage and possible ignition of hydrocarbons.

HAZARD CONTROL MEASURES: Training to reduce the potential of coming in contact with high voltage and preventing employee's exposure to dangerous electrical equipment.

The T/R control panel is to be locked out at the panel disconnect when not in use. This disconnects both control and high voltages. The grounding strap switch at the T/R is in the open position except when used to ground the T/R during maintenance.

### **DO NOT CLOSE STRAP DURING OPERATION**

Electrical and instrumentation interlocks are built into the system to automatically cut off power to the WESP before an explosive gas can form in the unit.

BACKGROUND:

The operation of the WESP can be divided into two parts, electrical and process. Problems in the electrical area will usually require assistance from an electrical or instrument technician, and this procedure will indicate when it is necessary to call for such assistance.

## WESP PROTECTIONS:

The electrical error messages and process interlocks will be discussed first since these must be satisfied before the WESP electrodes will energize. These same interlocks will also shut the WESP down during operation.

The following electrical interlocks read out on the WESP control panel:

- AC Overcurrent
- T/R High Oil Temperature
- SCR High Temperature
- Under Voltage
- Over Voltage
- SCR Unbalance
- Controller Loss of Memory
- Loss of Line Sync.

The AC Overcurrent implies that there is an electrical short in the system. The T/R and SCR are rectifiers and high oil temperature results if the rectifier overheats. An electrician should be called if these signals appear. The SCR Unbalance, Controller Loss of Memory, and Loss of Line Sync will also require outside help. The Under Voltage and Over Voltage warnings mean that the power being supplied (in this case, from the Guam Power Authority) has a voltage excursion, and the unit will be down until the power comes back within limits.

The following are process interlocks:

- Low WESP Exit Gas Temperature
- Low Water Flow to Spray Nozzles
- Two Kiln Feed Valves Open
- Two Kiln Ash Valves Open

An explosive gas mixture in the WESP is avoided by running at a high enough concentration of water vapor (steam) in the unit that the oxygen concentration is kept below 5 percent. An explosive mixture cannot form until the oxygen level reaches about 10 percent. If the gas exiting the WESP is above a certain temperature and water saturated (i.e., water is flowing to the spray nozzles and saturating the gas), then an explosive mixture cannot be present. The first two process interlocks shut down the power to the WESP if either of these two conditions are not met. The kiln feed and ash valve interlocks serve a similar purpose - if these valves are both open, air (oxygen) will be pulled into the WESP and an explosive mixture could be formed.

## START-UP PROCEDURE:

1. Heat the kiln shell temperature above 400°F.
2. Turn on the steam sweep gas to the kiln and steam to the WESP.
3. The ID fan must be drawing the hot gas from the boiler through the WESP.
4. Put process water to the solenoid water supply valve.
5. Allow water in the WESP sump to rise to the normal sump operating level.
6. Turn on the WESP water recirculation pump to supply water to the spray nozzles in the WESP.
7. The gas exiting the WESP must be at operating temperature.
8. Turn on the power to the WESP electrodes.

## OPERATING PROCEDURE(S):

1. The WESP slowly fouls during operation as solids and oils collect on the WESP tubes and electrodes. Operationally, this fouling causes the WESP secondary voltage to drop. As the voltage drops, the WESP solids removal efficiency drops. Three procedures are used to clean the WESP and bring the voltage back up. They are listed below in the order that they should be used.
  - A. If voltage degrades below the minimum level, operate the deluge wash system by turning off the current to the WESP and sending water to the spray nozzles at the top of the WESP. This provides a good cleaning for the WESP tubes.
  - B. If Procedure A does not recover the voltage, turn off power to the WESP and open the blowdown line to pump out the WESP sump. Cut off the make-up water or throttle the flow back so the sump level drops as the WESP sump is pumped out. Drop the level in the sump as low as possible. This removes the bulk of the solids from the sump. At the end of this pumpdown, return the blowdown to the normal flow and turn on the make-up water. When the recirculation water has reached the minimum level, restart the WESP.

- C. Solids buildup in the WESP will eventually become so great that the plant has to be shut down and the WESP opened and physically cleaned. This is typically done every one to two months.
2. If the WESP power trips out because of a low exit gas temperature, the reason for the low temperature must be found and corrected before the WESP is restarted. Typically, low temperature is caused by an air leakage upstream of the WESP, or a problem with the WESP steam injection.
3. If the WESP power trips out because of low flow to the internal spray nozzles, the reason for the low flow must be determined and corrected before the unit can be restarted.

#### OPERATING LIMITS:

- Outlet Gas Temperature                    198 °F Minimum
- Recirculation Flow                        35 gpm Minimum
- Blowdown Flow                            5 - 7 gpm
- Secondary KVA                            10 KV Minimum
- Spark Interval, seconds                3 - 10

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **LOADER/TRACK LOADER**

PURPOSE: To clean under and around the conveyors in the feed preparation area. To move or relocate material from one point to another.

HAZARDS IDENTIFIED: Physical harm to nearby personnel due to crushing.

HAZARD CONTROL MEASURES: Notify personnel in the work area prior to performing work. Maintain proper clearance.

### OPERATING PROCEDURE(S):

The following procedure will be understood by front end loader operators prior to use of the equipment:

1. Review and understand Heavy Equipment Operation SOP, OPS 102.
2. Only trained and authorized personnel are allowed to operate this machine.
3. Perform a visual check of the machine before starting. Walk completely around the machine, and clear the area of personnel and obstructions.
4. Before driving the machine, adjust the seat and fasten the seat belt.
5. Carefully check overhead clearance before operating in areas with overhead obstructions (e.g. power lines, overhead lights, and building doors) that could cause an accident.
6. Before moving the machine, **SOUND THE HORN** to warn nearby personnel.
7. Operate at speeds slow enough to ensure complete control of the machine. Travel slowly in congested areas or on rough ground.

8. When the bucket is at work, keep the engine speed at full throttle, and operate in the first (1st) gear transmission range.
9. Use gear range two (2) for traveling purposes.
10. Keep the loader on relatively level ground when possible.
11. Avoid wheel spin.
12. Approach a stockpile with the engine at full governed speed. Keep the bucket flat, working into the material at or near ground level. As the bucket penetrates the material, raise the bucket slightly. When the material fills to the top of the spillboard, roll the bucket all the way back. Raise the bucket to provide ground clearance and, at the same time, disengage the forward travel of the loader. Back away from the pile in an arc, and proceed to dumping area.
13. Do not operate this machine in a condition of extreme fatigue or illness. Do not operate this equipment while using prescribed medicine unless approval is received from your supervisor. Be especially careful at the end of a work shift.
14. Never try to get on or off the machine while it is moving. A serious injury or death could result.
15. Be careful cleaning around electrical panels. Report all broken wires immediately to Leadman or Shift Supervisor, so he can contact an electrician to do the necessary repair.
16. When approaching corners or blind spots, **SLOW DOWN** and **SOUND THE HORN** to warn oncoming traffic.
17. Operator should never be over 50 feet away from machine with engine running.
18. When machine is traveling, bucket or fork should be as close to the ground as possible.
19. Operator should never leave the bucket or fork off the ground when machine is unattended.
20. When using man basket, operator should **NEVER** leave machine unattended for any reason.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 21, 1995

TITLE: **LOADERS - RUBBER TIRE**

PURPOSE: To use as forklift. To move or relocate material from one point to another.

HAZARDS IDENTIFIED: Dangers associated with the operation of heavy equipment.

HAZARD CONTROL MEASURES: Proper training and procedures.

### **OPERATING PROCEDURE(S):**

1. Read and understand the SOP on Heavy Equipment Operation (SOP OPS 012).
2. Before driving the machine, adjust the seat and fasten the seat belt.
3. Carefully check overhead clearance before operating in areas with overhead obstructions (e.g., power lines, overhead lights, and building doors) that could cause an accident.
4. When the bucket is at work, keep the engine speed at full throttle, and operate in the first (1st) gear transmission range.
5. Use gear range two (2) for traveling purposes.
6. Keep the loader on relatively level ground when possible.
7. Avoid wheel spin.

8. Approach the stockpile with the engine at full governed speed. Keep the bucket flat, working into the material at or near ground level. As the bucket penetrates the material, raise the bucket slightly. When the material fills to the top of the spillboard, roll the bucket all the way back. Raise the bucket to provide ground clearance and, at the same time, disengage the forward travel of the loader. Back away from the pile in an arc, and proceed to dumping area.
9. Only trained and authorized personnel should be allowed to operate any heavy equipment or machinery.
10. **DO NOT** jump on or off the machine.
11. Perform a visual check of the machine before starting. Walk completely around the machine, and clear the area of personnel and obstructions.
12. Before moving the machine, **SOUND THE HORN** to warn nearby personnel.
13. When approaching corners or blind spots, **SLOW DOWN** and **SOUND THE HORN** to warn oncoming traffic.
14. Operator should never be over 50 feet away from machine with engine running.
15. When machine is traveling, bucket or fork should be as close to the ground as possible.
16. Operator should never leave any bucket or fork off the ground when the machine is unattended.
17. When using man basket, operator should **NEVER** leave machine unattended for any reason.

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **HEAVY EQUIPMENT OPERATIONS**

PURPOSE: To become familiar with the equipment and the task being performed.

HAZARDS IDENTIFIED: Dangers associated with the operation of heavy equipment.

HAZARD CONTROL MEASURES: Proper training and procedures.

### OPERATING PROCEDURE(S):

1. Operators must be aware of what they are doing.
2. **DO NOT OPERATE EQUIPMENT WHEN FATIGUED.**
3. Know the machine - understand **ALL** control functions.
4. Use the machine for its intended use.
5. Understand **ALL** control functions before starting the engine.
6. After starting and while operating, observe instruments and warning lights.
7. Investigate any unusual indications or noises in the machine.
8. Only trained and authorized personnel are allowed to operate any heavy equipment or machinery. Equipment operators shall be qualified to operate heavy equipment in accordance with SOP OPS 014, "Qualifications to Operate Heavy Equipment."
9. **DO NOT** jump on or off the machine.
10. Perform a visual check of the machine before starting. Walk completely around the machine, and clear the area of personnel and obstructions.

11. Before moving the machine **SOUND THE HORN** to warn nearby personnel.
12. Maintain clear vision of all work and travel areas. Keep windows and mirrors clean.
13. Never use the bucket as a brake except in an emergency. It could catch on the ground and cause a severe stop and personal injury.
14. Release the parking brake before moving the machine. The brake could burn or be damaged if the machine is driven with it applied.
15. Never work or walk under a raised bucket.
16. Never leave bucket or fork off the ground when the machine is unattended.
17. Seatbelts must be worn at all times during operation.

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **TRACKHOE OR EXCAVATOR**

PURPOSE: To remove material from ditch.

HAZARDS IDENTIFIED: Physical harm to nearby personnel due to crushing.

HAZARD CONTROL MEASURES: Notify personnel in the work area prior to performing work. Maintain proper clearance.

### OPERATING PROCEDURE(S):

1. Review and understand Qualifications to Operate Heavy Equipment (SOP OPS 014) and Heavy Equipment Operation (SOP OPS 012).
2. Only trained and authorized personnel are allowed to operate these machines.
3. Perform a visual check of the machine before starting. Walk completely around the machine, and clear the area of personnel and obstructions.
4. Before operating the machine, adjust the seat and fasten the seat belt.
5. Carefully check overhead clearance before operating in areas with overhead obstructions (e.g., power lines and overhead light) that could cause an accident.
6. Before moving the machine, **SOUND THE HORN** to warn nearby personnel.
7. Operate at speeds slow enough to ensure complete control of the machine. Travel slowly in congested areas or on rough ground.
8. When the bucket is at work, keep the engine speed at full throttle.
9. Keep the machine on relatively level ground when possible.

10. Do not operate these machines in a condition of extreme fatigue or illness. Be especially careful at the end of a work shift.
11. Never try to get on or off the machine while it is moving. A serious injury or death could result.
12. Be careful cleaning around electrical panels. Report all broken wires immediately to Leadman or Shift Supervisor, so he can contact an electrician to do the necessary repair.
13. When approaching corners or blind spots, **SLOW DOWN** and **SOUND THE HORN** to warn oncoming traffic.
14. Operator should never be over 50 feet away from machine with engine running.
15. Operator should never leave any bucket off the ground when machine is unattended.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 21, 1995

TITLE: **QUALIFICATIONS TO OPERATE HEAVY EQUIPMENT**

PURPOSE: To ensure the safety of employees while operating heavy equipment; to protect equipment from damage.

HAZARDS IDENTIFIED: Unqualified equipment operators.

HAZARD CONTROL MEASURES: Evaluate the qualifications of operators of heavy equipment.

### **OPERATING PROCEDURE(S):**

1. An operator is provided training on the equipment to be operated.
2. An employee must be observed operating within all the guidelines of the Safety Rules and demonstrate proficiency in operating the machine for which he is qualifying.
3. Then, and only then, can he be certified on that machine.
4. The Shift Supervisor does the testing.
5. An Equipment Certification Form is filled out, signed, and dated by the Shift Supervisor.
6. A copy of the certificate is put in the medical/training file and the administration file.

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 21, 1995

**TITLE:** **REFRIGERATION/CHILLER OPERATION**

**PURPOSE:** To chill the off-gas and condense additional water and PCBs prior to passing the gas through the High Efficiency Mist Eliminator.

**HAZARDS IDENTIFIED:** Electrical, pressure, burn, and PCBs.

**HAZARD CONTROL MEASURES:** Normal safeguards for working on mechanical equipment while in the area of the refrigeration system. The internal parts of the heat exchanger are contaminated with PCBs and protective clothing should be worn when working in the unit.

### **OPERATING PROCEDURE(S):**

1. Start cooling tower pumps.
2. Turn "On" main power circuit.
3. Fully open suction and discharge valves on the compressor. Valves on control lines and pressure should be fully opened and then closed back one round.
4. Open refrigeration and coolant circuit valves.
5. Turn on the bypass coolant pump. Turn "On" the pump motor starter. Observe pump discharge pressure reading.

**NOTE:** Ensure the crankcase has had ample time to heat (2 hours).

6. Turn "On" the refrigeration system.

7. Turn "On" the system pump.
8. Check oil levels after 10 hours of operation. The sight glass on the side of the crankcase should be 1/4 to 1/2 full.

**OPERATING LIMITS:**

CONTROL	CUT-OUT	CUT-IN	DIFFERENTIAL
Temperature	N/A	32°F	2°F
Suction Pressure	40 psig	N/A	15 psig
Suction Safety (PLC Reset)	30 psig	N/A	15 psig
Discharge Safety (Manual and PLC Reset)	375 psig	N/A	N/A
Oil Safety (Manual and PLC Reset)	9 psig	N/A	N/A

## OPERATIONS SOP

REVISION DATE: NOVEMBER 21, 1995

TITLE: **FILTER PRESS OPERATION**

PURPOSE: To remove solids from water.

HAZARDS IDENTIFIED: Mechanical hazards such as pinch points, electrical hazards. High pressure hazards stemming from:

- A. The possibility of the feed stock "blowing" out from between the plates.
- B. Hydraulic system leaks contacting eyes or skin.
- C. Solid particles dislodged when washing plates with high pressure washer.

Toxic hazards caused by PCB's attached to the solids filtered out by the media.

HAZARD CONTROL MEASURES: Lockout/Tagout when cleaning or doing repairs. Remain clear when closing plates. Regular inspections of gaskets and hydraulic lines. Use rubber gloves and face shield when using high pressure washer.

### OPERATING PROCEDURE(S):

1. Ensure hydraulic system has the required oil level.
2. Supply a minimum of 100 psi and maximum of 125 psi air pressure to unit.
3. Set the hydraulic toggle valve to "close" position.
4. Establish flow through unit.

5. Do not exceed maximum filtrate flow. The sludge pumpout rate must be less than the clarifier influent rate to maintain the proper level in the clarifier. If no water is being pumped to the clarifier, do not pump out sludge. If the liquid level in the clarifier falls below the liquid level in the surge tank, the clarifier will float, causing serious damage to the clarifier piping and clarifier.
6. Feed sludge to the clarifier until the feed pressure reaches 100 psig and the filtrate flow is below 1 gpm. This ensures a dry cake, and thus minimizes residuals.

#### CLEANING PROCEDURE:

1. Shut off flow through unit.
2. Blow air through unit to remove excess water.
3. Disconnect air.
4. Retract hydraulic ram.
5. Separate plates and scrape media with plastic paddle.
6. If required to high pressure wash, wear rubber gloves and face shield in addition to normal PPE.

#### OPERATING LIMITS:

- Operating Pressure      100 psig Maximum
- Filtrate Flow            20 gpm Maximum

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 21, 1995

TITLE: **WATER CARBON**

PURPOSE: To remove organic compounds and trace PCBs from the process wastewater.

HAZARDS IDENTIFIED: Organic compounds in the process water and trace amounts of PCBs.

HAZARD CONTROL MEASURES: Avoid contact with the liquid in the system.

### **OPERATING PROCEDURE(S):**

The L-4 Absorber must be degassed before being put into operation.

1. Remove the 16-inch diameter lid and add clean water at a slow rate (5 to 10 gpm) into the outlet port of each absorber until the tanks are filled.
2. Allow the tanks to set for 24 hours with the lid off to degas. During this time, add additional liquid as the liquid level drops due to gas displacement.
3. Reinstall the lids. Torque the closure ring bolt to 60 foot pounds and tighten the lock nut.
4. Valve the carbon units so the water passes through the two units in series.

### **SYSTEM OPERATION:**

In the discussion below, the carbon that the water enters first will be called the (first) lead carbon, and the carbon that is piped directly to the Clean Water Tank will be called the (second) lagging carbon.

- During operation, the lead carbon unit may become saturated with PCBs to the point that they are passing through the first unit into the second unit. If this occurs, the General Superintendent will issue instructions to change out the saturated carbon unit. Unless such direction is received, do not alter the flow of water through the carbon.
- Monitor the pressure drop through the carbon tanks. The tanks are rated for 9 psig, and should not be operated above 7 psig. If pressure exceeds 7 psig during normal operations, the lead carbon should be backwashed. See procedure below.

#### CARBON CHANGEOUT PROCEDURE:

- A. Valve the units so that all the water is passing directly through the lagging carbon and no water is passing through the lead carbon.
- B. Unbolt and remove the port on top of the lead carbon.
- C. Open the drain valve on the bottom of the carbon vessel and drain the water. This water will be pumped from the sump to the WWTP.
- D. After the carbon has drained completely, use a drum vacuum cleaner to remove the carbon from the vessel. Use only drums labeled "1A2X/400S." These drums are approved by the United Nations for sea transport of hazardous waste.
- E. While emptying the vessel, take at least a four-ounce sample of carbon from the top, approximately middle, and bottom of the carbon in the vessel. Label these samples "Spent Water Carbon," and record the location, time, and date.
- F. Weigh the filled drum. Label the drum "Spent Water Carbon," and record the gross weight, date, and carbon vessel number (1 or 2) on the drum. Also record this information in the shift log.
- G. Add fresh carbon to the vessel.
- H. Reattach the loading flange at the vessel. Torque the closure ring bolt to 60 foot pounds and tighten the lock nut.
- I. Change the valves so that the older becomes the lead carbon vessel and the fresh carbon is the lagging carbon.

## BACKFLUSHING PROCEDURE:

1. Valves the units so that all the water passes directly through the lagging carbon and no water is passing through the lead carbon.
2. Valve the lead carbon so that water from the treated water tank will pump into the outlet pipe and then discharge through the inlet pipe to the dirty water hold tank.
3. Backflush for 15 to 20 minutes at as high a flow rate as possible. Check the backwash water to make sure its clear.
4. When backflushing is complete, rearrange valves as before and resume operation.  
**NOTE:** Check valving out very carefully due to the number of valves in this system.

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 21, 1995

**TITLE:** **FLOCCULATION TANK**

**PURPOSE:** Flocculate small particulates in the wastewater into larger particles so they can be removed by settling.

**HAZARDS IDENTIFIED:** The sludge contains high levels of PCB and dioxin. Surfaces where polymer or polymer solution have been spilled will be slippery.

**HAZARD CONTROL MEASURES:** Clean up any sludge spills immediately and dispose of any material generated during the cleanup as a PCB waste. Clean up all polymer spills immediately. Use surgical gloves when handling the wastewater or sludge and dispose of the gloves as PCB-contaminated material.

### **OPERATING PROCEDURE(S):**

1. When the polymer mix/feed tank liquid level drops below one (1) foot, mix additional polymer.
2. Polymer Mixing Procedure:
  - a. Measure the distance from the liquid surface to the fill line that is one (1) foot from the top of the tank.
  - b. Measure out the polymer to be added.
  - c. Add the required amount of water, turn on the mixer, and add the pre-measured polymer.
  - d. Agitate the polymer for ten (10) minutes, then turn off the agitator.

3. Calibrate the polymer addition rate by removing the tygon tube from the addition point at the inlet to the flocculation tank and allow the polymer to run into a graduated cylinder for a timed period. Note test results in the log.
4. Check flocculation efficiency by dipping a clean beaker into the flocculation tank to sample the water. Look through the beaker. Clumps of floc should be visible. As the floc settles, the water should be clear (not turbid). After the test, pour the contents of the beaker back into the Flocculation Tank. Note test results in the log.
5. Sludge can be recycled from the bottom of the clarifier to the Flocculation Tank if required. This will aid floc formation if the solids content of the wastewater falls too low to build a good floc.

#### OPERATING LIMITS:

- Polymer Mix Ratio in the Mix/Feed Tank      20 pounds (2 gallons) polymer per tank foot (23.5 gallons) of water.
- Polymer Addition Rate      One (1) ml/sec (based on 20 gpm water flow) (0.96 GPH).
- Polymer Addition Calibration Frequency      Once/Shift.
- Flocculation Efficiency Test      Once/Shift
- Clarifier Sludge Recycle Rate      0 to 4 gpm.

## **OPERATIONS SOP**

REVISION DATE: JANUARY 19, 1996

TITLE: **PARTICULATE FILTER AND CARBON BYPASS - SURGE TANK OPERATION**

PURPOSE: The bypass system allows the particulate filters and carbon tanks to be taken off line. This would happen if these units had to be shut down for repair, or if an upset condition in the clarifier produced water with a high particulate loading that caused excessive bag changeouts. Excess contaminated water is stored in the Surge Tank. The bypass would continue until the problem was eliminated, or until the Surge Tank was full to its allowable capacity and the BCDP shut down.

HAZARDS IDENTIFIED: Mis-operation could result in overflowing the Surge Tank.

HAZARD CONTROL MEASURES: Carefully monitor the Surge Tank level.

### **OPERATING PROCEDURE(S):**

There are two configurations of the bypass mode depending on whether or not the boiler is in use. The bypass mode that uses potable water must be used if the boiler is operating. The bypass mode that recirculates water from the Clarified Water Tank should be used if the boiler is not operating.

### **BYPASS USING POTABLE WATER:**

If process flow to the Treated Water Tank stops, this bypass will engage automatically. When the level in the Treated Water Tank drops to a low set point, a valve will open automatically and add potable water to the tank. This ensures a steady supply of process water. Since no water is treated, the level in the Surge Tank will increase rapidly. Excess water will automatically overflow into the Surge Tank. This level must be monitored and the BCDP shut down before the Surge Tank reaches its upper level limit.

## BYPASS USING TREATED WATER:

If process flow to the Treated Water Tank stops and the boiler is not operational, the bypass switch on the computer screen in the control panel can be activated. This closes a solenoid and stops the flow of water from the Clarified Water Tank to the particulate filters. Another solenoid closes the flow from the Treated Water Tank to the process water line, and a third solenoid valve opens to allow the clarified water to be pumped into the process water line. Since no water is treated, the level in the Surge Tank will rise. Because water is being recirculated, the accumulation in the Surge Tank will be much slower than when using the potable water bypass mode. The level must still be monitored and the BCDP shut down before the Surge Tank reaches its upper level limit.

## SURGE TANK OPERATION:

Monitor the liquid level in the 26-foot diameter Surge Tank. The clarifier holds 5000 gallons and the secondary containment tank holds 3970 gallons per foot. Maintain 1.26 feet of the volume of the secondary containment tank for the clarifier secondary containment. Maintain an additional foot for freeboard. The total liquid level in the tank will not exceed 1.74 feet (1'-9"). This is about 7000 gallons of storage.

As soon as the water treatment operations can be returned to normal, start working off the water in the secondary containment tank. The secondary containment tank should normally be empty. Do not exceed the capacity of the water treatment plant when working off the excess contaminated water. This water should not be processed during heavy rain because the storm water will place additional burdens on the treatment plant.

## OPERATING LIMITS:

- Clarifier Secondary Containment Tank Level                  1.74 feet (1'-9") Maximum

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **WASTEWATER BAG FILTER UNITS**

PURPOSE: To remove particulate from the wastewater.

HAZARDS IDENTIFIED: The filter sludge will contain high levels of PCB and also dioxins. The filters are under pressure and should be vented and then opened carefully to prevent water from spraying on the operator. Used filter media should be disposed of as a PCB waste.

HAZARD CONTROL MEASURES: Clean up any sludge spills immediately and dispose of any material generated during the cleanup as a PCB waste. Use surgical gloves when handling the wastewater or sludge and dispose of the gloves as PCB-contaminated material. Isolate filter from the rest of the system before opening.

### **OPERATING PROCEDURE(S):**

1. Water leaving the Clarified Water Tank passes through one of two bag filters that are piped in parallel.
2. When the pressure drops across either the bag filter or cartridge filter exceed the rated amount, or sufficient flow to prevent the Clarified Water Tank from overflowing cannot be maintained, switch to the other filter and change out the filter element that is restricting flow. The changeout procedure is as follows:
  - a. Open valves so that flow is going to both filters in parallel.
  - b. Isolate the filter that is plugging by closing the liquid inlet and outlet valve to that filter.
  - c. Remove and replace plugged filter element.

**OPERATING LIMITS:**

- Filter Feed Rate 0 to 40 GPM
- Bag Filter Operating Pressure 75psig
- Bag mesh size 70 micron (nominal 1 micron)

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **CLARIFIER**

PURPOSE: Allows the flocculated solids to settle and oil to collect on the surface of the wastewater. The discharged wastewater should be very low in suspended solids and free oil. Since most of the PCBs will be on the solids or in the water, the clarifier removes PCBs from the wastewater.

HAZARDS IDENTIFIED: The clarifier sludge will contain high levels of PCB and also dioxins. In the unlikely event that it becomes necessary to enter the clarifier tank, consult with H&S to determine if the clarifier is a permitted confined space.

HAZARD CONTROL MEASURES: Clean up any sludge spills immediately and dispose of any material generated during the cleanup as a PCB waste. Consult H&S before entering the clarifier tank. Use surgical gloves when handling the wastewater or sludge and dispose of the gloves as PCB-contaminated material.

### **OPERATING PROCEDURE(S):**

1. Water gravity flows from the flocculation tank into the clarifier.
2. Record the solids level in the bottom of the clarifier. If the level cannot be observed through the FRP tank, put a stick into the top of the clarifier to feel the top of the sludge and measure the sludge level.
3. Check the top surface of the liquid in the clarifier for oil or other floating material. If over 2 inches of floating oil accrues, remove the oil by gravity draining it through the 1-inch nozzle in the oil layer. (Note: Envirochem will move the existing nozzle after the clarifier is place.)

4. Clean water gravity flows out of the clarifier into the Clarified Water Tank.
5. The water level in the clarifier must never fall below the level in the surge tank. If this happens, the clarifier can float and damage both the clarifier and connecting piping.

**OPERATING LIMITS:**

- Clarifier Feed Rate                    0 to 40 GPM
- Sludge Level in Clarifier Bottom    1 to 3 Feet

## OPERATIONS SOP

REVISION DATE: NOVEMBER 22, 1995

TITLE: **ROTARY KILN REACTOR (CALCINER)**

PURPOSE: Provides safe direction for preparing the calciner to receive waste materials.

HAZARDS IDENTIFIED: Rotating parts, pinch point, skin exposure to diesel fuel, burns.

HAZARD CONTROL MEASURES: Guards properly installed, lockout/tagout, static testing of fuel lines before use, Level "D" PPE.

### DEFINITIONS:

#### **ROTARY KILN REACTOR SHELL**

The calciner shell is three (3) feet in diameter by thirty-nine (39) feet overall length (4 feet feed and discharge sections and approximately 30 feet hot-zone section) and is constructed of 1/2-inch thick minimum carbon steel. The shell has been rolled, welded, and bolted together at the hot-zone section to make up the full length.

#### **TIRES**

The shell rotates on two (2) forged steel tires, weldless and seamless, type ASTM A551, Class C, machined to a 250 micro-inch finish all over. Each tire has a solid rectangular cross section with a 5-inch face by 3 inches thick. Each tire has a hardness of approximately 180 to 210 brinell.

#### **TRUNNIONS**

The shell rotates on four (4) solid steel trunnion wheels. The trunnions have been flame hardened.

#### **BURNER ZONES**

There are four (4) thermocouples between the rotating shell and the stationary furnace housing. The four areas of the shell around these thermocouples are called zones.

**NOTE:** The equipment vendor has supplied a detailed manual for this equipment. The manual should be studied before operating the equipment.

**OPERATING PROCEDURE(S):**

**EQUIPMENT START-UP SEQUENCE**

1. Open appropriate manual air and fuel block valves.
2. Turn on panel power. Note: Alarm will sound and need to be silenced.
3. Start the following equipment:
  - a. Air compressor
  - b. Shell rotation
  - c. Fuel pump number 1 or 2
  - d. Combustion air fan.
4. Push the "reset" button on the burner panel.
5. Press "limits set" switch on burner panel. The orange light marked as "purging" will illuminate. If after 3 to 5 minutes the "purging" light does not go out, check to make sure the air valve limit switch is made.
6. Press "burner start" to energize the main fuel valves. Note: Have one burner toggle switch per zone in the "on" position.
7. Manually latch up the propane maxon valve.
8. Depress the low fuel pressure bypass switch. Latch up the fuel oil maxon valve. Release bypass switch once the pressure has risen to normal.
9. If the burner fails to light, the red failure light will illuminate and an audible alarm sounds. To clean the alarm and attempt to relight, turn the toggle off and then back on. The green flame on light and the yellow run light indicates a proven flame.
10. If all burners fail, you must repeat the sequence.
11. Due to overdesign of the burners, the following is a general temperature guideline:
  - a. 4 burners (one per zone), 450°F minimum control
  - b. 7 burners (spaced evenly), 900°F
  - c. 11 or 12 burners, 1000°F at 1.25 TPH, feed moisture 8 percent
  - d. 13 or 14 burners, 1000°F at 1.25 TPH, feed moisture 13 percent.
12. Secondary air to burners not in use should be left blocked until needed to prevent "tiger-striping."

## EQUIPMENT SHUT-DOWN SEQUENCE

1. Stop the flow of soil.
2. Allow the soil to empty out of the unit while maintaining destruction (ash discharge temperature).
3. Use caution while allowing soil to empty since the soil acts as a heat sink.
4. Once the majority of the soil has emptied, begin lowering the temperature approximately 200°F per hour.
5. Begin shutting off burners as needed to continue the cool down cycle.
6. Continue shell rotation until the shell temperature drops below 200°F.

**Warning:** **Stopping shell rotation before the furnace temperature drops below 200°F can cause serious damage to the shell by allowing it to sag in the center.**

7. When the shell temperature drops below 200°F, stop the shell rotation.
8. Shut off oil pumps and air blower.

## OPERATING LIMITS:

- Zone Temperature      1100°F Maximum

(Note - The manual gives a maximum temperature on 1000°F, but the unit has been operated at 1100°F for extended periods).

- Bed Volume      15% Maximum

## OPERATIONS SOP

REVISION DATE: JANUARY 18, 1996

TITLE: **HIGH EFFICIENCY MIST ELIMINATOR (HEME)**

PURPOSE: The HEME removes any residual particulate solids and micron and submicron size water and organic aerosol mists from the gas stream. PCBs attached to this material are also removed.

HAZARDS IDENTIFIED: Pinch points associated with vessel lids. Possible skin and airborne exposure to PCB's and/or dioxins when changing HEME elements or draining liquid from the HEME.

HAZARD CONTROL MEASURES: Use Level C PPE and work gloves when pulling the elements out of the HEME tank. Use Level C PPE for the actual changeout of the elements until the old element is removed and sealed in a drum. Use Level D PPE with chemical resistant gloves when installing a new HEME element and prefilter bag. Wear work gloves and Level D PPE when reinstalling the HEME element. Decontaminate wrenches and any other tools that come in contact with the inside of the HEME.

When removing oil from the HEME drain, wear Level D PPE with a full face shield and chemical resistant gloves. The container used to transport the oil must be sealed before it is moved.

### INITIAL START-UP PROCEDURE:

The start-up procedure should be completed before the HEME is placed on line.

1. Ensure that the HEME element is installed with a prefilter over the element in both HEME tanks.

2. With the drain valve closed, attach a liquid receiver to the HEME drain line. Ensure that the connection is airtight and open the drain valve.
3. Open the inlet and outlet gas lines to the HEME that will be on line and close the inlet and outlet gas lines to the off-line HEME.
4. The off-gas flow can now be started through the system.

#### OPERATING PROCEDURE(S):

1. Monitor the HEME pressure drop and take the HEME off line if the pressure drop reaches the operating limit.
2. Check the liquid drain tank once per day. Before there is any chance of the drain tank filling up, empty the tank using the following procedure:
  - a. Close the drain valve
  - b. Remove the lid from the drain tank. Do not allow any liquid to spill. Estimate the volume of liquid collected. Pour the liquid into a drum labeled "HEME Drain Liquid" for storage. The drum should also be labeled PCB WASTE. Enter this information in the log. The drum must be stored in secondary containment. Storing the drum inside of the APC Building would provide that secondary containment.
  - c. Replace the drain tank and reopen the drain valve. Check to ensure that the system is airtight.
3. If liquid accumulates in the HEME tank, a high level alarm will sound. This liquid can be drained through a drain valve in the bottom of the tank. Because the HEME operates under vacuum, the unit must first be taken out of service by switching the gas flow to the other unit before draining. After the unit is drained, it should be placed back on line. This liquid should be stored separately from the liquid that drains from the inside of the element.

#### CHANGING HEME TANKS:

When a HEME can no longer be operated because of excessive pressure drop, or any other reason, the HEME is taken off line and replaced by the second HEME. Do not operate the

HEME above the maximum pressure drop - this can damage the element. The change procedure is as follows:

1. Ensure that the HEME element is installed in the new tank with a prefilter over the element.
2. With the drain valve closed, attach a liquid receiver to the drain line of the new HEME. Ensure that the connection is airtight and open the drain valve.
3. Open the inlet and outlet gas lines to the new HEME.
4. Close the inlet and outlet gas lines to the off-line HEME.

#### CHANGING HEME ELEMENTS:

A supervisor must determine if the HEME elements require changing and be present when the elements are changed. If there is a chance that the prefilter has plugged and caused the high pressure drop, then only the prefilter needs to be changed. If there is doubt, install a new prefilter and see if that solves the problem. The elements for a changeout cost \$2400. The prefilter costs \$300.

The procedure for changing the elements is in the equipment file and should be reviewed before the procedure is started. The following items should be kept in mind.

1. The Monsanto procedure calls for sliding the HEME cage over a horizontal pipe. Because our cage is only 6 feet high, the cage can be set vertically on plastic sheeting on the floor.
2. The inner and outer elements that are installed are different. Ensure that they are installed in the proper order.
3. Gaskets are in stock for use between the cage flange and the HEME flange. Clean the metal surfaces well before installing the new gasket.
4. Ensure that the system is airtight and no gas can bypass the HEME element. Follow the Monsanto procedure for tightening the bolts on the element.

#### OPERATING LIMITS:

- Normal Pressure Drop      2 to 10 inches WC
- Maximum Pressure Drop      25 inches WC

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **FEED BELT OPERATION**

PURPOSE: Provides feed to reactor.

HAZARDS IDENTIFIED: Pinch points, rotating equipment.

HAZARD CONTROL MEASURES: All guards to remain in place. Personnel will be aware of the hazards associated with this equipment. Proper lockout/tagout during repairs.

### **OPERATING PROCEDURE(S):**

1. Reactor is at operating conditions with inlet knifegates operating.
2. Set feed controller on manual at about 15 percent output. Start feed belt by depressing "feed belt on" switch. Start apron feeder by energizing "on" switch.
3. Monitor operation of belt. If it is operating properly, set controller at desired feed rate.
4. If necessary to remove guards or come into close proximity to moving parts, shut down feed belt and apron feeder.

Shut breaker off at local panel and lockout according to lockout/tagout procedure.

Contact H&S to determine proper personal protective equipment (PPE).

## OPERATIONS SOP

REVISION DATE: NOVEMBER 22, 1995

TITLE: **SCRUBBER OPERATION AND MAINTENANCE**

PURPOSE: To remove particles entrained in the gas stream.

HAZARDS IDENTIFIED: Burns from hot water, possible skin exposure to PCB and dioxin.

HAZARD CONTROL MEASURES: Personnel performing tasks of putting into service will exercise caution when opening valves and starting pumps. Personal protective equipment (rubber gloves at a minimum) will be used when cleaning equipment interiors. Proper lockout/tagout procedures will be used when opening equipment.

### OPERATING PROCEDURE(S):

It is essential that the proper sequence be used **each** time the scrubber is put in operation. The scrubber fluid should be turned on first to allow all internal surfaces to be fully wetted and to allow wetted elbow to be filled. When properly adjusted, the convergent approach surfaces above the venturi throat will be thoroughly wetted. No large dry areas are permitted below the edge of the inlet collar. (Air flow at the venturi inlet will assist in scrubbing fluid distribution.)

When shutting down the unit, first shut off the air flow, then the scrubber fluid.

### EQUIPMENT START-UP SEQUENCE

1. Open the venturi water outlet and put air to scrubber level control pump.
2. Start scrubber make-up pump, adjust rotometers on venturi to the required flow.
3. Begin air flow through scrubber system and adjust venturi throat to obtain desired differential pressure (automatic controller).

5. As a minimum, wear rubber gloves when removing the cleanout plates.
6. Contact H&S to determine proper PPE before cleaning out.

NOTE: The Impinjet scrubber is not effective in this system. No water will be run through this unit.

#### **EQUIPMENT SHUTDOWN SEQUENCE**

1. To shut system down, cease air flow, stop flow of make-up water to system, and allow system to be pumped down.

#### **OPERATING LIMITS:**

- Pressure Drop                    35 - 40 in WC
- Water Flow to Venturi        5 to 8 gpm
- Water Flow to Impinjet      0 gpm

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **EAGLE CRUSHER CLEANING**

PURPOSE: To safely clean the crusher of buildup and jams.

HAZARDS IDENTIFIED: Pinch points, rotating parts, crush points, and possible skin exposure to PCB-contaminated soil.

HAZARD CONTROL MEASURES: Use lockout/tagout procedure. Wear Level C PPE.

### **OPERATING PROCEDURE(S):**

1. Assemble the necessary tools, shovels, scrapers, pry bars, safety belt, and lanyard.
2. While wearing Level C, use extended scraper to clean buildup off the floor of the hopper.
3. If not possible to use extended scraper, block open grisly bars.
4. Push toggle to engine stop, close cover, and lock closed.
5. Don safety belt, climb into hopper via platform, and shovel.
6. When finished and clear of hopper, remove block from grisly.
7. Unlock access door.
8. Restart engine and proceed.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **COOLING TOWER OPERATION**

PURPOSE: To provide cooling water for heat exchange in primary condenser and water cooled condenser on refrigeration unit.

HAZARDS IDENTIFIED: Water treatment problems of scale, corrosion, sludge, and algae which could foul the cooling tower and heat exchanger.

HAZARD CONTROL MEASURES: Introduction of water treatment chemicals to control scale, corrosion, sludge, and algae. Maintain the proper blowdown.

### **START-UP PROCEDURE:**

1. Check line-up of cooling water valves from the cooling tower through the primary condenser and refrigeration unit water cooled condenser.
2. Check power supply to ensure power is on.
3. Make sure personnel are clear of unit and start the cooling tower circulation pump, then the cooling tower fan. Listen for unusual noises or vibration.
4. Once circulation is initiated, start the chemical injection pumps for water treatment. Ensure that the chemical feed tanks are not empty.

### **OPERATING PROCEDURE(S):**

1. Check for system leaks and proper flow across hot water basin and chemical control.
2. Routinely sample the cooling water to test for:
  - a. pH
  - b. Hardness

- c. Bromine
  - d. Chlorides
  - e. Conductivity/TDS
  - f. Phosphonates
  - g. Sulfites.
3. Chemical injection pumps will be adjusted and tower blowdown adjusted to stay within parameters.
4. The cooling tower is equipped with a vibration switch which will shut down the fan if excess vibration occurs.

#### OPERATING LIMITS:

• pH	7.0 to 9.0
• Hardness	< 700
• Bromine	To be determined
• Chlorides	To be determined
• Conductivity/TDS	3500 mm
• Phosphonates	Ca/1200 10 to 20 ppm
• Sulfites	To be determined

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 22, 1995

**TITLE:** **INDUCED DRAFT FAN**

**PURPOSE:** To draw PCB laden vapors and particles through the process system for cleaning and recovery and maintain the system under a slight negative pressure.

**HAZARDS IDENTIFIED:** Escaping contaminated material due to unit pressure becoming positive.

**HAZARD CONTROL MEASURES:** Draft is controlled at negative pressure. The ID fan is on the emergency generator to maintain the vacuum in case of power failure.

### **OPERATING PROCEDURE(S):**

1. Check system to ensure that gas line valves are properly open upstream of ID fan.
  - a. Valve from the cyclone to the WESP
  - b. Valve from the primary condenser to the venturi
  - c. HEME inlet
  - d. HEME outlet.
2. Check system to ensure that gas line valves are properly open downstream of ID fan.
  - a. Valving for air carbon unit inlet
  - b. Valving for air carbon unit discharge.
3. Check ID fan speed controller SIC-580 to be sure it is in manual and 0 percent output.
4. Close breaker for motor starter.

5. Make sure personnel are clear of unit and start the ID fan. Fan should ramp up to approximately 500 RPM. (NOTE: ID fan can be started locally at the fan or remotely in the control room.)
6. Set PIC-210 reactor draft controller to desired setpoint, -0.10 to -0.50, and put controller in auto.
7. The ID fan has variable speed drive motor on it which will speed up or slow down to control setpoint of PIC-210, which is located on the ash end of the rotary reactor.
8. To protect the ID fan, an amp clamp has been placed to prevent the ID fan from ramping up and tripping out on high amps. The ID fan has both vacuum and pressure relief valves.
9. During operation, the following parameters will be monitored:
  - a. Fan RPM
  - b. Fan suction pressure
  - c. Fan discharge pressure.

#### OPERATING LIMITS:

- Reactor Vacuum 0.10 to 0.50 inches WC
- ID Fan Vacuum 82 inches WC maximum
- ID Fan Pressure 54 inches WC maximum
- Fan RPM 1400 maximum

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **RADIAL STACKER**

PURPOSE: To transfer hot ash from calciner to ash bins.

HAZARDS IDENTIFIED: Pinch points, rotating equipment, hot ash, dust.

HAZARD CONTROL MEASURES: Stay clear of moving equipment, use proper PPE when handling hot ash.

### **START-UP PROCEDURE:**

1. Make sure all guards are in place.
2. Check that conveyor is lined up to proper ash bin.
3. Make sure all personnel are clear of conveyor.
4. Make sure power is on to motor starter.
5. Start conveyor.

### **MAINTENANCE OR SHUTDOWN PROCEDURE:**

1. Locate stop button to shut down conveyor. NOTE: Make sure belt is empty of ash if possible.
2. Follow lockout/tagout procedure on conveyor to ensure there is no accidental start-up while personnel are working on it.
3. Perform necessary work.

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 6, 1995

**TITLE:** **SPILL NOTIFICATION AND RESPONSE**

**PURPOSE:** The prevention of uncontrolled discharges is a high priority at the BCDP site. This SOP outlines procedures for responding to uncontrolled discharges.

**HAZARDS IDENTIFIED:** Exposure to PCB and dioxins, slip hazards.

**HAZARD CONTROL MEASURES:** Use Level D PPE at a minimum. If exposure to PCBs appears possible, use Level C PPE.

The following will also be performed:

- Provide training for all employees to perform their work and to respond to emergencies.
- Help personnel recognize and understand the potential hazards to health and safety associated with operation of an BCDP facility.
- Foster a high level of environmental consciousness.
- Formal classroom and informal on-the-job training.

### **OPERATING PROCEDURE(S):**

Critical factors in spill or release control are the ability of the person discovering the release to act immediately, know the procedures, and know where to obtain help. When a spill is discovered, the employee will notify the Shift Supervisor immediately.

## **NOTIFICATION FOR SPILLS AND REQUIRED REPORTS**

The Shift Supervisor will note in the operating record the time, date, and details of any incident. A written incident report will be submitted by the Project Manager to OICC as soon as possible.

## **IDENTIFICATION OF HAZARDOUS MATERIALS (SPILL/RELEASE)**

Once a spill/release situation has been reported to the Shift Supervisor, he/she will then be responsible for evaluating the hazardous materials, determining the extent of the release, the cause, and the quantity released.

## **CONTROL PROCEDURES:**

The control procedure required will depend on the nature of the release. The following items will be considered:

1. Discontinue the flow of city water, electricity, process water, or fluids if they might aggravate the situation.
2. Initiate evacuation of area if required.
3. Check the integrity of the containment system.
4. Shut down all refueling operation if required.

## **CLEANUP PERSONNEL WILL:**

- Make sure all unnecessary personnel are removed from the hazard (spill) area.
- Put on appropriate protective clothing and equipment.
- Isolate BCDP area by closing drainage valves, shutting down sump pumps, fuel pumps, etc.
- If a flammable waste is involved, remove all ignition sources, and use spark- and explosion-proof equipment and appropriate clothing in containment and cleanup areas.
- Try to stop or minimize the leak or release, if possible, with materials stocked for emergencies.

- If containment wastewaters are present, clear surrounding area and determine the major components of the spilled or leaked material.
- Clean up any spilled or leaked material using hazardous waste containers, absorbent pillows, and oil spill absorbent material.
- Decontaminate all equipment used during cleanup operations; results from analyses will determine disposal method for waste generated from decontamination operations.
- Replace leaking containers; repair of damaged containers is not recommended.

Spillage of material outside the BCDP on noncontaminated surfaces also requires prompt response. Spills or releases of waste materials outside a facility shall be handled in the same manner as a spill inside a facility. In addition, cleanup personnel will:

- Decontaminate the area as necessary by removing contaminated soil, rocks, coral, sandbags, etc., or by washing contaminated surfaces with appropriate washing agents.
- Obtain a representative sample of spill or wash residues and submit for analysis. (Results from these analyses will determine how waste will be disposed.)
- Package the spilled material in containers and return to the contaminated area or place inside staging area pending appropriate disposal.

#### PREVENTION OF RECURRENCE OR SPREAD OF RELEASES OR SPILLS:

During the event, the Shift Supervisor will coordinate the measures to reduce the potential for releases or spills to occur, recur, or spread to other sections of the facility. Measures to mitigate this potential may include:

- The curtailment of all deliveries
- The containment, collection, and disposal of released wastes
- The shutdown of all affected operations
- The removal of the affected wastes to safe areas.

Following the incident, an investigation will be performed to assess root causes and take corrective actions to prevent recurrence.

#### **POST EMERGENCY EQUIPMENT MAINTENANCE:**

After a release/spill event, all emergency equipment enlisted in the event will be cleaned, decontaminated, or restocked so that it will be available for future use. SOP No. 002 - "Decontamination" requires that equipment used in a potentially contaminated area be checked for contamination before leaving the site. Appropriate personnel protection equipment is used as necessary during this procedure. Equipment that is contaminated will be taken to the decontamination pad where the equipment will be cleaned using high-pressure water wash.

#### **SPILL CONTROL EQUIPMENT:**

Contaminated material handled at the BDCP are PCB-contaminated wastewater, soil, and fines (dust). Equipment and material for the construction of temporary dikes and collection of spills, including shovels, front-end loader, bobcat, trackhoe, and containment drums, will be maintained on site. Portable pumps and hoses will also be available.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 22, 1995

TITLE: **OFF-GAS BYPASS OPERATION**

PURPOSE: To operate the system without the WESP, boiler, and primary condenser when required because of system problems.

HAZARDS IDENTIFIED: The bypass valve close to the WESP is difficult to access. If the off-gas ducting is blocked because the valves are changed in the wrong order, there can be a release of off-gas to the environment.

HAZARD CONTROL MEASURES: Use a safety belt when climbing to the valve near the WESP. Open and close valves in the order shown in this procedure.

### **OPERATING PROCEDURE(S):**

1. Open the valve between the Multicloner and the Venturi Scrubber.
2. Close the valve between the Venturi Scrubber and the Primary Condenser.
3. Close the valve between the Multicloner and the WESP.

To duct the gas back through the WESP and Primary Condenser (i.e., go off the bypass):

1. Open the valve between the Venturi Scrubber and the Primary Condenser.
2. Open the valve between the Multicloner and the WESP.
3. Close the valve between the Multicloner and the Venturi Scrubber.

Valves must be opened and closed in the sequence shown above. If the off-gas stream is blocked at any time during this changeover, there will be a release of off-gas to the environment.

## **OPERATIONS SOP**

REVISION DATE: NOVEMBER 6, 1995

TITLE: **ASH HANDLING OPERATIONS**

PURPOSE: This procedure describes the proper handling and movement of treated soil (ash).

HAZARDS IDENTIFIED: Ash discharge temperatures range between 600°F and 700°F. Ash releases heat very slowly, and ash that has been stockpiled for several days can still cause burns.

HAZARD CONTROL MEASURES: Extreme care must be exercised when handling or sampling ash solids. Wear gloves and use a scoop or pan to collect the ash. Ash discharge temperatures from the ash moisturizer will be in the 140°F to 200°F range.

### **DEFINITIONS:**

#### **ASH**

For the purposes of this SOP, ash will be defined as the treated solids discharged from the BCDP calciner unit. For practical purposes, ash material includes:

- Material collected in one or more of the three (3) ash bins located at the discharge of the radial stacker conveyor.

#### **CLEAN ASH**

Ash that has been shown, by analytical results, to meet treatment criteria. Having met treatment criteria, clean ash may be used as final fill for the excavated areas.

#### **CONTAMINATED ASH**

Ash that is awaiting analysis to confirm whether or not it meets treatment criteria, or ash that has been shown by analytical results not to meet treatment criteria.

## **ASH BINS**

Storage locations for ash, while awaiting analytical results, will be in one of three (3) ash storage bins arranged in a 140-degree arc pattern at the discharge end of the Radial Stacker Conveyor. Each bin has a capacity of approximately 24 tons, 72 tons total storage, which equates to 3 days of production at anticipated calciner feed rates of one (1) ton per hour (90 percent operating factor), respectively. Fugitive emissions will be controlled by spraying the ash piles with potable water or clean process water.

## **PROCESS UPSET**

Should a process upset condition occur during the operation of the BCDP unit, discharge ash (following the upset) will be stored in a separate bin to minimize the possibility of contaminating potentially clean ash. Once the upset condition has been resolved, the process operator may elect to return ash discharge to the previous bin, if the bin was not full.

## **SYSTEM OPERATION:**

### **SAMPLING AND ANALYSIS**

Samples are pulled periodically from the Radial Stacker Conveyor discharge in accordance with the type and frequency specified in SOP No. 037, Soil and Ash Sampling.

## **ASH MEETING TREATMENT CRITERIA**

### Receipt of Analytical Results

Upon receipt of analytical results, confirming that the ash in a specific bin has met the treatment criteria, the Shift Supervisor will notify the Equipment Operator accordingly.

The Equipment Operator(s), under direction of the Shift Supervisor, will use a front-end loader and dump truck to load and move the ash to the ash staging area.

**NOTE:**      Exercise care to prevent overloading of the truck to minimize spillage as the ash is being transported.

## **ASH NOT MEETING PCB TREATMENT CRITERIA**

### Receipt of Analytical Results

If the analytical results confirm that the ash in a specific bin does **not** meet the treatment criteria for PCB, the process operator will notify the Shift Supervisor who will arrange for the ash removal from the bin. This material will be returned to the feed preparation building and reprocessed.

### Contaminated Ash

Contaminated ash will be removed from the bin via a front-end loader and trucked to the feed preparation building by dump truck. Care must be exercised not to overload the truck; thereby minimizing spillage during transport.

### Decontamination

Once the contaminated ash has been moved, the haul vehicle and the front-end loader will be decontaminated in accordance with SOP No. 002.

## **BACKFILL:**

When an excavated area has been confirmed as clean through chemical testing, treated soil will be used as backfill. Fill will be placed in 6-inch lifts and roller compacted between each lift. Water spraying will be utilized as needed to aid compaction. Compaction will be to approximately 80 percent of Standard Proctor.

A buffer zone of at least 30 liner feet will be maintained between the excavation area and the placement of the treated fill. A coral "rock" filter will be installed following every 300 feet of excavation with the final three filters placed at 50-foot intervals.

## OPERATIONS SOP

REVISION DATE: NOVEMBER 8, 1995

TITLE: **CONTINUOUS EMISSIONS MONITORING (CEM) SYSTEM**

PURPOSE: The Continuous Emissions Monitoring System, or CEM, monitors the off-gas stream at several critical locations during plant operation. Sample locations are at the inlet to the carbon drums, outlet to the first carbon drum to check for breakthrough, and the vent (stack). The off-gas is drawn into the detection system where the organic components are separated and their concentration measured using a Flame Ionization Detector (FID).

HAZARDS IDENTIFIED: Fire hazard from the hydrogen generator is minimal due to the low volume of hydrogen generated; burn hazards are present at heat traced tubing, air heater, and internal oven. There could be PCBs and dioxins in the samples from the system.

HAZARD CONTROL MEASURES: Do not open the equipment to perform any adjustments, measurements, maintenance, parts replacement, or repairs until all power supplies have been disconnected.

**Only** properly trained technicians should work on any equipment with power still on.

OPERATING PROCEDURE(S):

The system is designed to sample each location about every 5 minutes. This information is transferred electronically to the control room console where the Shift Supervisor can watch for any excursions from established in-control operating conditions. The information is also stored in a database so that a permanent record of the off-gas quality can be maintained.

NOTE: ANALYZER START-UP SHOULD BE PERFORMED BY A QUALIFIED INSTRUMENT TECHNICIAN.

Daily Checks:

- Hydrogen generator water sump level should be checked and refilled as needed.
- Check hydrogen generator control panel for normal operation.
- Check pressure and flows against the start-up settings. If they are different, notify the technician.
- Check heat tracing and air heaters for normal temperature.
- Check printer paper.
- Check analyzer status, only the green normal light should be on.
- Check air dryer for proper operation.
- Alarms are self clearing; if an alarm light is on, wait 15 minutes and check again. If the alarm is still on, notify the technician.

Shutdown of CEM:

- Long-term shutdown must be done by a **Qualified Technician**.
- Short-term shutdown may be accomplished by simply closing the sample valves. The heaters and analyzer should be left on.

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 8, 1995

**TITLE:** **BCDP RESTART APPROVAL**

**PURPOSE:** This procedure lists the approvals required to restart the BCDP system after an outage.

**HAZARDS IDENTIFIED:** This SOP details the restart approval requirements only, therefore, there are no safety issues in the procedure. There are safety considerations applicable to restarting any of the equipment and these considerations are detailed in other SOP's and vendor manuals.

**HAZARD CONTROL MEASURES:** The standard notification procedure will be for the Shift Supervisor to notify the General Superintendent of a shutdown situation requiring restart approval above the Shift Supervisor level. The Shift Supervisor will notify other site personnel as necessary. The Project Manager will notify off-site personnel.

**DEFINITIONS:**

### **RESTART**

Restart is defined as bringing the entire BCDP facility or the primary systems back into operation following any of the events listed in this SOP.

**OPERATING PROCEDURE(S):**

### **DOCUMENTATION**

All restarts will be documented in one of the two following forms:

- BCDP Restart Approval Matrix
- Shift Supervisor Log Book.

## **MINOR SYSTEM UPSETS**

Events which do not require an approval past the General Superintendent will be documented in the Operations Log Book. Such events include minor feed upsets, standard equipment maintenance, etc.

When a minor system upset occurs, the Shift Supervisor will be notified immediately by the Process Operator, as appropriate, and their verbal approval solicited for the anticipated corrective action(s). The event, time, and corrective action taken will be entered into the Supervisor Log Book.

## **MAJOR SYSTEM UPSETS**

Events which require advice and/or approval beyond the Shift Supervisor's level will be documented on the attached form. Such events include major equipment failure, required redesign, maintenance requiring extended system shutdown, etc.

Under the occurrence of a major system upset, the Shift Supervisor will notify the General Superintendent. The Shift Supervisor will be responsible for soliciting and completing the approved corrective action as well as documenting the event and the required approvals.

Recognizing that the prime objective is to safely return the BCDP unit to service as quickly as is possible, **Verbal Approvals** may be given for the selected corrective action(s). The Shift Supervisor will document the event and the selected corrective action at the bottom of the form. Formal approval will be documented by initialing and dating in the appropriate box of the form. The General Superintendent is responsible for securing the required approval signatures and verifying that the original completed form is filed in the project files.

### ATTACHMENT:

- BCDP RESTART APPROVAL

	<b>TYPE OF FAILURE</b>	<b>SHIFT SUPERVISOR</b>	<b>SITE HEALTH AND SAFETY</b>	<b>BCDP SITE QA/QC</b>	<b>GENERAL SUPERINTENDENT</b>	<b>PROJECT MANAGER</b>
A	<i>POWER FAILURE WITHOUT EQUIPMENT DAMAGE</i>	•			•	
B	<i>POWER FAILURE RESULTING IN EQUIPMENT DAMAGE</i>	•	•			
C	<i>WASTE FEED SYSTEM PLUGGAGE</i>	•				
D	<i>MINOR INSTRUMENT FAILURE (NO-CRITICAL)</i>	•				
E	<i>MAJOR INSTRUMENT FAILURE OF A CRITICAL PROCESS CONTROLLER</i>	•				
F	<i>UNEXPLAINABLE PROCESS FAILURE</i>	•				
G	<i>MAJOR C.E.M. FAILURE (HARDWARE/SOFTWARE)</i>	•	•			
H	<i>MAJOR MECHANICAL FAILURE (CRITICAL COMPONENTS TO THE PROCESS)</i>	•	•			
I	<i>ENVIRONMENTAL INCIDENT: PROCESS OR PERSONNEL SAFETY PROBLEMS. (ANY EVENT THAT MAY PRODUCE DAMAGE TO EQUIPMENT OR INJURY TO PERSONNEL).</i>			•	•	
J	<i>BACK-UP SYSTEM FAILURES:</i>					
	• <i>EMERGENCY GENERATOR</i>					
	• <i>EMERGENCY INSTRUMENT AND PROCESS AIR</i>				•	
	• <i>EMERGENCY REACTOR DRIVE UNIT</i>				•	

**BCDP RESTART APPROVAL SIGN OFF SHEET**

<b>DATE:</b>	<b>COMMENTS:</b>
<b>PROBLEM:</b>	
<b>CORRECTIVE ACTION TAKEN:</b>	<b>COMMENTS:</b>
<b>SHIFT SUPERVISOR:</b>	

## OPERATIONS SOP

REVISION DATE: NOVEMBER 6, 1995

TITLE: **FEED CHUTE CLEANOUT PROCEDURE**

PURPOSE: To remove blockages in the kiln feed chute.

HAZARDS IDENTIFIED: Harmful vapors, contaminated soil, hot gases and surfaces, and moving equipment.

HAZARD CONTROL MEASURES: Lockout/tagout of feed conveyor and process equipment in accordance with shutdown procedures and SOP 001. Prevent burns by not touching metal surfaces during cleanout operation. Dress in Level C whenever opening the feed chute for work to remove a pluggage or for inspection.

### OPERATING PROCEDURE(S):

The following procedure will only be performed during a Wet Electrostatic Precipitator (WESP) outage. This will prevent the possibility of an explosive gas mixture in the system.  
NOTE: If the pluggage cannot be removed in two hours or less, it may be necessary to go to the process bypass system (see SOP 031, Off-Gas Bypass Operation).

1. Lockout/tagout the feed conveyor breaker.
2. Lockout/tagout the Wet Electrostatic Precipitator (WESP).
3. Continue the water circulation to the spray nozzles on the WESP spray bars.
4. Notify the Shift Supervisor before opening the knife gates due to the large amount of air that will be pulled into the system. Place the ID fan in manual operation.

5. Open the top and bottom knife gates. This can be accomplished by closing the supply air header to the valves.
6. Inspect the feed chute. If blockage is present, use the special cleanout tool to remove the buildup.
7. It may be necessary to cycle the knife gates during this operation. Take care that the cleanout tool is secured with a rope so that it will not slip inside the reactor.
8. When the pluggage has been removed, open the supply air to the knife gates and let them cycle.
9. Start the feed conveyor at a low feed rate. NOTE: It may be necessary to jog the belt periodically to clear the belt.
10. After the feed rate has been reestablished, start the WESP per SOP.
11. Spillage on the feed deck can be dumped on the belt through the feed chute. Spillage on the ground will be taken to the feed preparation building.
12. Dispose of all PPE properly.

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 6, 1995

**TITLE:** **WASTEWATER DISCHARGE SAMPLING**

**PURPOSE:** This SOP defines the method for sampling wastewater for PCBs prior to analysis and discharge to verify that it meets the PCB treatment limit.

**HAZARDS IDENTIFIED:** Contact with PCB-contaminated liquids, splash protection, sharp objects (broken glass).

**HAZARD CONTROL MEASURES:** Proper training to procedures, protective clothing.

### **BACKGROUND:**

Wastewater is generated by water driven off the soil during processing, rain water, decontamination water, etc. This water will be pumped to two 5000-gallon tanks after being processed by the BCDP water treatment system. A 24-hour composite will be collected in a 6-gallon nalgene carboy from a needle valve located at the influent header of the wastewater storage tanks after the cartridge filter. An aliquot of this composite will be collected for analysis. No water will be discharged prior to analysis by BCDP and FENA laboratories and approval from Navy OICC.

### **MATERIALS:**

- 6-gallon nalgene carboy
- Funnel
- 1 liter amber bottles with Teflon-lined caps
- Bottle labels
- Chain-of-Custody Forms.

## **RESPONSIBILITY:**

### **LABORATORY MANAGER**

The Laboratory Manager will review the laboratory data and determine whether or not the water can be discharged in accordance with Navy directives. He will inform the OICC representative about the laboratory results and instruct the Project Manager of OICC approval or disapproval for discharge. He will periodically monitor the Operator's sampling method for inconsistencies and perform the Laboratory Chemist's responsibilities for this SOP during his absence.

### **LABORATORY CHEMIST**

The Laboratory Chemist will supply the Operators collecting the sample with sampling materials. He will receive the samples, log them into the system, assign the laboratory sample numbers, and store them for on-site analysis. Additionally, he will prepare the respective QA samples for delivery to FENA laboratory and prepare the FENA laboratory Chain-of-Custody Form (attached).

### **OUTSIDE OPERATOR**

The Operators will collect the discharge water samples and complete the BCDP Chain-of-Custody Forms (attached) except for the laboratory sample number. The Operators will document any unusual characteristics of the sample (color, odor, cloudiness, etc.). The Operator will deliver the sample to the laboratory and give it to the Laboratory Chemist along with the Chain-of-Custody Form.

## **SAFETY PROCEDURES:**

### **TRAINING**

The QA/QC Manager will provide training to ensure that employees understand the intent of this procedure and that employees are qualified to implement the procedure.

### **PROTECTIVE CLOTHING**

Protective clothing will be used during sample collection to prevent potential injury to sampling personnel through splashing. This will also minimize possible contamination of the sample. The following protective clothing will be worn along with Level D PPE:

- Nitrile gloves.

## OPERATING PROCEDURE(S):

- Obtain the appropriate number of clean 1-liter bottles from laboratory personnel for site and QA samples.
- Attach labels to the bottles. Complete initial, date, and time sections on the label in waterproof ink.
- Remove the filled carboy and replace it with a clean one. Thoroughly mix the contents of the full carboy. Transfer samples directly from the carboy into the bottles using a funnel. One sample is for the BCDP site laboratory, the other is for the FENA laboratory.
- Close the bottles and store them in the sample refrigerator located in the sample preparation shed. At the beginning of each shift, the Outside Operator will deliver the samples to the laboratory together with the completed Chain-of-Custody Forms.
- Laboratory personnel will complete the sample number on the Chain-of-Custody Form and prepare the FENA Chain-of-Custody Form. The sample will be packed in blue ice for delivery to FENA laboratory.
- Laboratory personnel will store the BCDP sample in the sample refrigerator to await analysis.
- Once every ten (10) samples, two (2) additional samples will be collected for spike and spike duplicate analysis. The Laboratory Chemist will instruct the Operators when this sample is due.

## DISPOSAL:

The balance of the carboy contents not used will be returned to the surge tank for disposal.

## OPERATING LIMITS:

- PCB Discharge Limit              < 1 ppb.

## ATTACHMENTS:

- BCDP-GUAM CHAIN-OF-CUSTODY
- FENA LABORATORY CHAIN-OF-CUSTODY

**BCDP-GUAM**  
**CHAIN-OF-CUSTODY**

Lab ID	Initials of Sampler	Sample Description	Date Sampled	Time Sampled	Preservative	Type of Container	Matrix	Analysis Required
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

TOTAL NUMBER OF SAMPLES _____

TOTAL NUMBER OF CONTAINERS _____

I CERTIFY SAMPLES ARE LABELED AND MATCH THE ABOVE DESCRIPTION

RELEASED BY _____

DATE _____

TIME _____

RELEASED BY _____

DATE _____

TIME _____

FENA LABORATORY  
CHAIN-OF-CUSTODY

CUSTOMER _____

JOB ORDER # _____

LAB ID # _____

Customer's Sample ID # or Name	Date Sampled	Time Sampled	Preservative	Number Container	Type of Container	Matrix	Analysis Required
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

(Cooler Temperature _____)

_____ UNUSED SAMPLE TO BE RETURNED TO CUSTOMER

_____ CONTACT BEFORE DISPOSAL

SAMPLED BY _____

AREA SAMPLED _____

# DAYS _____

TOTAL NUMBER OF SAMPLES _____

TOTAL NUMBER OF CONTAINERS _____

PHONE # _____

FAX # _____

CONTACT FOR REPORT/QUESTIONS _____

DATE _____

TIME _____

DATE _____

TIME _____

I CERTIFY SAMPLES ARE LABELED AND MATCH THE ABOVE DESCRIPTION

RELEASED BY _____

DATE _____

TIME _____

RELEASED BY _____

DATE _____

TIME _____

## **OPERATIONS SOP**

**REVISION DATE:** NOVEMBER 20, 1995

**TITLE:** **SOIL AND ASH SAMPLING**

**PURPOSE:** This SOP defines the method for taking confirmatory trench samples and feed soil samples for PCBs. It also defines the method for sampling the reactor product to prevent the use of contaminated processed soils in the backfill. These samples will also verify compliance with the contract specifications for soils excavation and backfill.

**HAZARDS IDENTIFIED:** Contact with PCB-contaminated solids, inhalation of dust-containing PCBs, sharp objects (broken glass), burns from hot ash samples.

**HAZARD CONTROL MEASURES:** Proper training, protective clothing.

### **BACKGROUND:**

Three types of soil samples will be collected on site: confirmatory trench samples, feed samples, and reactor product samples. Trench soil sample will be collected as specified in the Excavation Plan. Six (6) feed samples will be collected per 24-hour period and composited. Reactor product samples will be collected from individual storage bins which represent one batch. Each batch will be stored until sample analysis verifies that the criteria for reuse has been met. The reactor product will then be reused for backfilling and regrading the trench.

### **MATERIALS:**

- 250 ml or 500 ml wide-mouth jars with Teflon-lined lids
- Bottle labels
- Chain-of-Custody Forms
- Sampling shovel
- Mixing tray
- Decontamination equipment.

## **RESPONSIBILITY:**

### **LABORATORY MANAGER**

The Laboratory Manager will review the laboratory data and determine whether or not the feed soil has been excavated to a sufficient depth and whether or not the reactor product can be used as backfill in accordance with Navy directives. He will also periodically monitor the Operator's sampling method for consistency. He will also perform the Laboratory Chemist's responsibilities for this SOP in his absence.

### **LABORATORY CHEMIST**

The Laboratory Chemist will supply the Operators collecting the sample with sampling materials. He will receive the samples, log them into the system, assign the laboratory sample numbers, and store them for on-site analysis. Additionally, he will prepare the respective QA samples for delivery to FENA laboratory and prepare the FENA laboratory Chain-of-Custody Forms.

### **OUTSIDE OPERATOR**

The Operators will collect the soil or reactor product samples and complete the BCDP Chain-of-Custody Forms (attached) except for the laboratory sample number. The Operators will document any unusual characteristics of the sample (color, odor, etc.). The Operator will deliver the sample to the laboratory and give it to the Laboratory Chemist along with the Chain-of-Custody Form.

### **QA/QC MANAGER**

The QA/QC Manager will provide training to ensure that employees understand the intent of this procedure and that employees are qualified to implement the procedure.

## **SAFETY PROCEDURES:**

### **PROTECTIVE CLOTHING**

Protective clothing will be used during sample collection to prevent potential exposure or injury to sampling personnel. Level "C" protective clothing will be worn during collection of trench and feed samples. Level "C" PPE includes:

- Tyvek
- Nitrile gloves
- Rubber steel-toe boots
- Full face respirator with cartridges.

The Level "D" protective clothing will be worn during collection of ash samples. Level "D" PPE for this activity includes:

- Safety glasses
- Rubber steel-toe boots
- Heat resistant gloves.

NOTE: Care must be exercised in collecting the reactor product samples due to the potential for burns from reactor product discharge temperatures which may be in excess of 200°F.

#### TRENCH CONFIRMATORY SOIL SAMPLING PROCEDURE(S):

- Obtain the appropriate number of clean bottles from laboratory personnel for site and QA samples.
- Attach labels to the bottles. Complete initial, date, and time sections on the label in waterproof ink.
- Collect surface samples as specified in the Excavation Plan. Collect samples directly from the exposed surface to a depth of 4 inches. Soil which has large rocky particles will be reduced in size by processing the sample through the sample grinder. One sample is for the BCDP site laboratory. Corresponding QA samples (10 percent) will be collected per guidelines specified in the QAP for the site and FENA laboratories.
- Close the bottles and deliver to the laboratory. Store in the sample refrigerator. Complete the required sections on the BCDP Chain-of-Custody Form (attached). After hours, store the sample in the sample refrigerator in the sampling shed next to the grinders until morning.
- Laboratory personnel will complete the sample number on the BCDP Chain-of-Custody Form and prepare the FENA Chain-of-Custody Form (attached) for samples going to FENA. The FENA QA sample will be packed in blue ice for delivery to the FENA laboratory.
- Laboratory personnel will store the BCDP sample in the sample refrigerator.

#### **FEED SAMPLING PROCEDURE(S):**

- Collect six individual samples during the day for a 24-hour composite feed sample. Every four hours, collect equal quantities of the material for the sample directly from the conveyor belt.
- Attach labels to the bottles. Complete initial, date, and time sections on the label in waterproof ink.
- Feed soil which has large rocky particles will be reduced in size by processing the sample through the sample grinder. One sample is for the BCDP site laboratory.
- Close the bottles and deliver to the laboratory. Store in the sample refrigerator. Complete the required sections on the BCDP Chain-of-Custody Form (attached). After hours, store the sample in the sample refrigerator in the sampling shed next to the grinders until morning.
- Laboratory personnel will complete the sample number on the Chain-of-Custody Form.
- Laboratory personnel will store the BCDP sample in the sample refrigerator to await analysis.

#### **REACTOR PRODUCT SAMPLING PROCEDURE(S):**

- While filling a particular reactor product bin, obtain the appropriate number of clean bottles from laboratory personnel for site and QA samples.
- Attach labels to the bottles. Complete initial, date, and time sections on the label in waterproof ink.
- Collect a reactor product sample from the ash conveyor every four (4) hours using a stainless steel dipper. Let cool and transfer into 250 ml glass jar. Samples which have large rocky particles will be reduced in size by processing through the sample grinder.
- Close the bottles and deliver to the laboratory. Store in the sample refrigerator. Complete the required sections on the Chain-of-Custody Forms. After hours, store the sample in the sample refrigerator in the sampling shed next to the grinders until morning.

- Laboratory personnel will complete the sample number on the Chain-of-Custody Form and prepare the FENA Chain-of-Custody Form when required. The FENA QA sample will be packed in blue ice for delivery to FENA laboratory.
- Laboratory personnel will store the BCDP sample in the sample refrigerator to await analysis. They will composite all the samples from particular bin and take a portion for the samples. Corresponding QA samples will be collected per guidelines specified in the QAP for the site and the FENA laboratories.

#### DECONTAMINATION:

- All field sampling equipment which comes in contact with soil or ash samples will be decontaminated between samples by thoroughly rinsing with water. The equipment will then be rinsed into a bucket with hexane stored in a squeeze bottle. Large, stationary equipment will be rinsed with water and wiped off with hexane. The equipment will then be dried, wrapped in aluminum foil, and stored in a clean area.
- Separate sampling equipment and grinders will be used for feed soil and ash samples to prevent cross contamination.

#### SAMPLE DISPOSAL:

- All samples will be disposed of after their holding time has expired or the required analyses have been performed by returning them to the feed piles.

#### ATTACHMENTS:

- BCDP-GUAM CHAIN-OF-CUSTODY
- FENA LABORATORY CHAIN-OF-CUSTODY

**BCDP-GUAM  
CHAIN-OF-CUSTODY**

Lab ID	Initials of Sampler	Sample Description	Date Sampled	Time Sampled	Preservative	Type of Container	Matrix	Analysis Required
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								

TOTAL NUMBER OF SAMPLES _____

I CERTIFY SAMPLES ARE LABELED AND MATCH THE ABOVE DESCRIPTION

RELEASED BY _____

TIME _____

RELEASED BY _____

TIME _____

**FENA LABORATORY**  
**CHAIN-OF-CUSTODY**

CUSTOMER _____	JOB ORDER # _____			LAB ID # _____			
Customer's Sample ID # or Name	Date Sampled	Time Sampled	Preservative	Number Container	Type of Container	Matrix	Analysis Required
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

(Cooler Temperature _____)  
 UNUSED SAMPLE TO BE RETURNED TO CUSTOMER       ARCHIVE SAMPLE  
 CONTACT BEFORE DISPOSAL      # DAYS _____  
 SAMPLED BY _____  
 AREA SAMPLED _____

TOTAL NUMBER OF SAMPLES _____  
 CONTACT FOR REPORT/QUESTIONS _____  
 RELEASED BY _____ DATE _____ TIME _____  
 RELEASED BY _____ DATE _____ TIME _____  
 TOTAL NUMBER OF CONTAINERS _____  
 PHONE # _____  
 FAX # _____

I CERTIFY SAMPLES ARE LABELED AND MATCH THE ABOVE DESCRIPTION  
 RELEASED BY _____ DATE _____ TIME _____  
 RELEASED BY _____ DATE _____ TIME _____

## **APPENDIX E**

### **RAPID START STACK TEST REPORT SUMMARY**

This summary is taken from: McDaniel, Paul, P.E., et al., 1995, "BCDP "Rapid Start" Source Emission Test Result, Bldg. 3009 Site Naval Station Sumay, Guam," SSR-2164-ENV, Naval Facilities Engineering Service Center, Port Hueneme, California, November 1995.

## 1.0 INTRODUCTION

This report provides results and documentation of air pollution source testing conducted by the Naval Facilities Engineering Service Center (NFESC) between 13 and 23 July, 1995 on the Base Catalyzed Decomposition Process (BCDP) thermal desorber treating PCB contaminated soil at the Building 3009 Navy Installation Restoration site, Naval Station Sumay, Guam. This round of testing was conducted during the so-called early start phase of the BCDP operation and should be considered preliminary because (1) not all the planned air pollution control equipment was installed and (2) the unit was not operated at full capacity. A second round of air pollution source testing will be conducted after the scheduled installation of additional air pollution control equipment. Exhaust gasses from the BCDP unit were tested for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDD's), and polychlorinated dibenzofurans (PCDF's), hydrogen chloride (HCl), volatile organic compounds (VOC), semi-volatile organic compounds (Semi-VOC).

### 1.1 REFERENCES - GENERAL

- (a) IT Corp. "TRANSITION PLAN" June 1993  
(PCB REMEDIAL ACTION, PWC, GUAM, M.I., Contract No. N47408 - 91 - D - 3043,  
Delivery Order 0009)

### 1.2 SITE BACKGROUND

A brief history of the Building 3009 site is provided in reference (a). The Public Works Center (PWC) Building 3009 housed a transformer repair shop where electrical transformers were cleaned and repaired from approximately 1952 to 1977. The associated transformer oil storage and recycling system was removed from service in 1977 when leakage was identified. Although soils in the immediate vicinity of the oil storage and recycling system were removed and disposed of, approximately 5500 tons of PCB contaminated soils and rock requiring treatment remain on site. The site soils are derived from coral rock and have little organic content below the uppermost soil horizon.

### 1.3 BCDP EQUIPMENT DESCRIPTION

The thermal desorber is an indirectly heated rotary kiln, fired on the outside of the kiln barrel with four banks of burners with each bank consisting of four oil fired burners. Note that both the burners and the thermal desorption and dechlorination process inside the kiln result in air emissions, but the focus of this report is on the emissions from the BCDP process inside the kiln. If required for permitting purposes, emissions from the burners heating the kiln can be estimated based on fuel consumption. Table 1 furnishes kiln labelplate data. The rotary kiln is rated for a maximum throughput of 2 tons of soil per hour. However, the air pollution control equipment was designed for a feed rate of 1.5 tons of contaminated soil per hour. Appendix D provides data sheets for BCDP rapid start (Quickstart) operation including kiln temperatures and feed rates. During the seven test runs, the kiln rotated within 1.25 and 2.0 revolutions per minute and processed between 0.48 and 0.79 tons of contaminated soil per hour (See Table 2. for kiln speed and feed rate average for each test run). Soil residence time in the kiln is on the order of one hour.

### 1.3 BCDP EQUIPMENT DESCRIPTION, continued

Temperatures outside the shell of the rotary oven were about 1060 F to 1100 F, treated soil "ash" exited the kiln at about 500 F, and exhaust gasses exited the kiln at about 340 to 400 F.

The air pollution control equipment downstream of the rotary kiln during the "rapid start" phase consisted of a multicyclone, venturi wet scrubber, high efficiency mist eliminator (HEME), and activated-carbon adsorption units, in that sequence. Additional equipment consisting of steam addition to the kiln sweep gas, a steam quench, a wet electrostatic precipitator, condenser, and a chiller/condenser will be installed before the next round of testing.

As part of the Base Catalyzed Decomposition Process (BCDP), sodium bicarbonate is mixed with the soil before feeding to the kiln. During the rapid start operation, sodium bicarbonate was added to the soil feed at approximately 1% by weight. Sodium bicarbonate promotes partial dechlorination of PCBs in the rotary kiln and is also thought to increase the effectiveness of the thermal desorption and decrease the formation of dioxins. Decomposition of sodium bicarbonate (baking soda) in the rotary kiln contributes to carbon dioxide in the exhaust gas.

TABLE 1: KILN LABELPLATE DATA

Size/Type: 3'-0" Dia.x 38'-0" Lg. Rotary Calciner [6560-3]
Feed Rate: 2 Ton/Hr max.      Shell Speed: 0.5 to 5 R.P.M.
(Wet weight basis)              Screw Jacks: 21" Travel
Manufacture: Renneburg Division of Heyl and Patterson Inc.

### 1.4 SAMPLING RATIONALE

Under the 1990 amendments to the clean air act, the EPA is tasked with developing emission standards for a list of "toxic air contaminants." The standards will be specific to the processes producing the emissions and are to reflect the "Maximum Achievable Control Technology". Emission standards for contaminated soil treatment facilities are not likely to be addressed until the year 2000 (see Federal Register, Vol. 59, pp 66850, December 28, 1994). Given this regulatory uncertainty it was decided to sample and analyze for a range of volatile and semi-volatile organic contaminants with the goal of identifying what contaminants are emitted in significant amounts. Additionally, it was decided that sensitive analysis directed at quantifying emissions of PCBs, chlorinated dibenzo-p-dioxins, and chlorinated dibenzo furans, and HCl was appropriate. Dioxins and furans are products of any combustion or high temperature process where chlorine is present in the fuel. HCl, hydrochloric acid, is also produced in combustion of chlorinated compounds. In an April 1995 telephone conversation with Hiroshi Dodahara, (202) 260-3959 (a U.S. EPA expert on PCB incineration, permitting), Mr. Dodahara indicated that the EPA is treating thermal treatment units as they would an incinerator during trial testing. He indicated that the emissions from a non-incineration thermal PCB treatment unit should be tested for particulate matter (PM),

## 1.4 SAMPLING RATIONALE, continued

hydrochloric acid (HCl), carbon dioxide (CO₂), oxygen (O₂), volatile organic compounds (VOC), semi-volatile organic compounds (SemiVOC) (including PCBs, dioxins, furans). The EPA may also require sampling for metals, if metals are present in the feed.

## 1.5 REFERENCES - AIR SAMPLING AND ANALYTICAL TEST METHODS

Source emission test sampling procedures and equipment were in accordance with the U.S. Environmental Protection Agency (EPA) Test Methods (most are published in Title 40, Code of Federal Regulations, Part 60 (40 CFR 60), Appendix A). California Air Resources Board (CARB) Method 421 was used for HCl determination. The following EPA Test Methods describe test system train configurations and procedures used for stack gas testing. The Test Methods also describe procedures to be used by the laboratories for analyzing the sample pollutant concentrations:

- Method 1. Sample and Velocity Traverses for Stationary Sources.
- Method 1A. Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts.
- Method 2C. Determination of Stack Gas Velocity and Volumetric Flow Rate in Small Stacks or Ducts (Standard Pitot Tube).
- Method 3A. Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedures).
- Method 4. Determination of Moisture Content in Stack Gases.
- Method 5. Determination of Particulate Emissions from Stationary Sources.
- Method 10. Determination of Carbon Monoxide Emissions From Stationary Sources.
- Method 23. Determination of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans From Stationary Sources.
- Method TO-14 Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Polished Canister Sampling and Gas Chromatographic (GCS) Analysis.
- Method 680 Analyze the extracts for PCBs using modified Method 680.

### EPA Solid Waste Test Methods:

SW-846, Method 0010 (Modified Method 5 Sampling Train) for polycyclic organic matter (POM). Determination of Destruction and Removal Efficiency (DRE) of semivolatile Organic Hazardous Compounds (POHCs) from incineration systems (PHS, 1967).

Method 8100 Target Compounds.

Method 8270 Analyze the sample for organic compounds.

### State of California Air Resources Board, Stationary Source Test Methods:

421. Determination of Gaseous Chloride and Fluoride In Emissions From Stationary Sources.

## 1.6 AIR SAMPLING AND ANALYSIS PROCEDURES

Table 2 summarizes the analyte classes, sampling and analysis methods used.

TABLE 2: ANALYTE CLASSES, SAMPLING AND ANALYSIS METHODS

ANALYTE	SAMPLING METHOD	ANALYTICAL METHOD
Dioxins, Furans	40 CFR Part 60, Method 23 (Modified by omission of Toluene rinses)	High resolution Gas Chromatography, High resolution Mass Spectrometry (HRGC/HRMS)
PCBs	SW-846, Method 10	High resolution GCMS
Semi-Volatile Organic Compounds	SW-846, Method 10	GCMS
Particulate Matter (PM) weight	40 CFR Part 60, Method 5	Gravimetric (weight) only
Volatile Organic Compounds (VOC)	EPA Method TO-14	Gas Chromatography, Mass Spectrometry
HCl	CARB Method 421	Ion Chromatography
Oxygen	40 CFR Part 60, Method 3A	On-line analysis (paramagnetic sensing)
Carbon monoxide	40 CFR Part 60, Method 3A	On-line analysis (infrared gas analysis)
Carbon dioxide	40 CFR Part 60, Method 3A	On-line analysis (infrared gas analysis)

The following presents a general overview of each test's equipment layout and procedures. Basically, exhaust gas is drawn from the stack and the contaminants are captured by some type of liquid, filter, or resin media, or captured in a container, for later analysis. All captured samples were shipped to a contract laboratory for analysis. Volatile organic contaminants (VOCs) were captured in an evacuated container (SUMA), as described below. A single VOC sample was taken. Sampling for other contaminants was performed in sets of three "runs." During the six to eight hour duration of each run, the sample probe was periodically moved (traversed) from point to point across the stack on two perpendicular diameters so that the sample was collected for an equal length of time from eight points in the stack spaced to represent equal areas of the stack. This procedure averages any differences in flowrate and concentrations within the stack. Stack gas oxygen, carbon dioxide, or carbon monoxide concentrations were analyzed immediately by on line instrumentation and readings recorded at each sampling traverse point, along with other data. Selection of the sampling entry point into the stack and the number and location of traverse points were in accordance with the requirements of EPA Method 1 (of 40 CFR Part 60). Absence of cyclonic flow was verified per the procedure of EPA Method 1. Stack gas velocity, stack gas dry molecular weight, and moisture content were determined by EPA Methods 2, 3, and 4, respectively.

**SUMA Canister:** An evacuated 6 liter ultra clean stainless steel vacuum canister was used for drawing a sample of exhaust gas for volatile organic compound analysis. The lab analyzed the gas sample for 62 standard target compounds of Test Method TO-14, and monitored for the presence of other non-target "tentatively identified compounds."

Sample train 2 is composed of three separate measuring systems; (1) is for analyzing, on a continuous basis, CO₂, CO, and O₂, (2) is for measuring stack temperature, and (3) is for determination of stack gas velocity and volumetric flow rate.

System 1 draws a portion of flue gas from the stack through tubing to the analyzers using a pump as the conveyor. Moisture is removed from the flue gas by condensing with an ice bath and collecting the water in a knockout trap. The flue gas is further polished of moisture by drawing it through a canister of "drierite" and then filtered for any particulate before it enters the pump. From the pump, the flue gas is pushed into a manifold from which it is distributed to each analyzer at a rate of 0.5 l/m. CO₂/CO is measured with a California Analytical Instrument (FUGI model ZRH) with non-dispersive and infrared gas analysis. O₂ is measured with a Servomex model 570A with paramagnetic sensing. System 2 is a thermocouple attached to a digital readout. System 3 is a standard pitot tube (coefficient of 0.99) connected to a 0-10 in. H₂O manometer.

Sample trains 3 and 4 used modifications of Methods 5 and 23 were used to test for HCl, VOC, PCB, PM, Chlorinated Dibenzo Furans and Chlorinated Dibenzo Dioxins.

NFESC modified Method 23 by omitting the use of toluene and performing both the front half rinses, the back filter holder half rinses, and the tubing and cooling coil rinses with acetone and methylene chloride only. To explain, the goal of sampling is to quantitatively collect all of the dioxins and furans drawn into the sampling probe. The sampling train consists of the probe, a glass fiber filter (in a filter holder), connecting tubing, a cooling coil, and the XAD resin trap. The dioxins and furans can be trapped in the filter, the XAD resin, or can stick to the walls of the probe, filter holder, tubing, or cooling coil. In order to collect all of the dioxins and furans, the probe, filter holder, tubing and cooling coil interior surfaces are rinsed with solvent and the solvent collected as part of the sample (along with the filter and the XAD trap). In the standard Method 23, the probe and upstream half of the filter holder (referred to as the front half) are rinsed with three rinses of acetone followed by three rinses of methylene chloride and then by three rinses of toluene. The downstream half of the filter holder is rinsed with three rinses of acetone. The connecting tubing, and the cooling coil are rinsed with three rinses of methylene chloride, followed by three rinses of toluene.

## 1.7 SOURCE EMISSION SAMPLING TEST SCHEDULE

Table 3 displays source emission stack outlet test schedule with kiln speed and feed rate information for each test run. Table 4 displays stack gas sampling data such as stack velocity and temperature.

TABLE 3: SOURCE EMISSION STACK OUTLET TEST SCHEDULE  
WITH KILN SPEED AND FEED RATE INFORMATION FOR EACH TEST RUN

DATE	LINE PROCESS	TEST/RUN	START TIME (approx.)	TOTAL TEST TIME (minutes)	KILN R.P.M. (avg.)	KILN FEED (avg. tons of soil fed/hr)
7/14/95	DIOXIN/FURAN	1/1	0935	360	1.25	0.79
7/15/95	DIOXIN/FURAN	1/2	0845	360	1.25	0.72
7/16/95	DIOXIN/FURAN	1/3	1030	360.6	1.25	0.67
7/16/95	DIOXIN/FURAN	1/4 (Blank)	1030	N/A	1.25	0.67
7/17/95	DIOXIN/FURAN	1/5	1435	480	1.25	0.48
7/18/95	VOLATILES	N/A	-	<5	-	-
7/19/95	PM/SEMIVOC/PCB	2/1	1600	480	2.0	0.52
7/20/95	PM/HCL/SEMIVOC/PCB	2/2	1740	480	1.75	0.57
7/20/95	PM/HCL/SEMIVOC/PCB	2/3 (Blank)	1740	N/A	1.75	0.57
7/22/95	PM/SEMIVOC/PCB	2/4	0900	480	1.80	0.77

Note: Shaded area indicates a voided test run. The post-test leak-check for this run was higher than allowed.

TABLE 4: STACK GAS SAMPLING DATA  
BCDP, NAVAL STATION SUMAY, GUAM, MARIANA ISLANDS

BUILDING 3009 SITE

SAMPLE I.D. (Test/Run)	H ₂ O %	AVG. STACK TEMP. (deg. F)	Avg. Stack Velocity (fps)	Actual Stack Flow (acfm)	Total Test Time (min.)	VOL. OF AIR SAMPLED (dscfm)	Dry Std. Stack Flow (dscfm)	Percent Isokinetic (%)
1/1	10.7	107.8	39.6	435	360	245.1	356	102.7
1/3	10.9	109.0	24.7	271	300.6	178.4	219	105.1
1/5	10.8	114.5	28.4	312	480	200.0	250	103.5
AVG. TEST 1	10.8	110.4	30.9	339			275	

SAMPLE I.D. (Test/Run)	H ₂ O %	Avg. Stack Velocity (fps)	Actual Stack Flow (acf m)	Total Test Time (min.)	VOL. OF AIR SAMPLED (dscfm)	Dry Std. Stack Flow (dscfm)	Percent Isokinetic (%)	
2/1	10.5	114.4	19.3	212	480	144.1	172	108.6
2/2	9.9	112.0	17.7	194	480	135.5	159	110.1
2/4	18.0	105.9	20.5	225	480	148.3	170	113.2
AVG. TEST 2	12.8	110.8	19.2	210			167	

**Table 5,  
PCB, HCl, and VOC Air Sampling Results for BCDP Rapid Start (July 1995)**

	PCBs	Volume sampled nanograms/ sample	stack flowrate dry std cu. ft.	sampling duration dry std cfm	tons soil fed minutes	PCB conc. microgr/ cu m	PCB emissions microgr/ hr	PCB % removal (assume 75 ppm in feed soil)
Test 2 Run 1	8755	144.1		172	480	4.2	2.15	627 99.9982
Test 2 Run 2	8938	135.5		159	480	4.6	2.33	629 99.9984
Test 2 Run 4	15682	148.3		169	480	6.2	3.73	1072 99.9980
<b>Average</b>	<b>11125</b>						<b>2.74</b>	<b>776.18 99.9982</b>
	HCL	Volume sampled micrograms	stack flowrate dry std cu. ft.	sampling time dry std cfm	tons soil fed minutes	HCl conc. grams / cu m	HCl emissions grams / hr	
Test 2 Run 2	220	135.5		159	480	4.6	0.057	15
Insignificant amounts of <b>semi-volatile contaminants</b> were detected; (lab report in appendix C).								
Carbon Monoxide ranged from 100 to 400 ppm during sampling; (field data in Appendix B).								
The following <b>volatile contaminants</b> were detected in a single Suma cannister grab sample:								
Contaminant	ppb volumetric	for relative comparison, OSHA PEL, ppb	NIOSH TLV, ppb	g/hr	kg/yr			
Propylene	4000	-	-	2	18			
Acetone	2800	1,000,000	250,000	1.4	12.5			
Benzene	340	1,000	100	0.3	2.7			
Tetrahydrofuran	280	200,000	200,000					
1,3-Butadiene	210	1,000,000						
Chloromethane	190	-	-					
2-Butanone	79	200,000	200,000					
Cyclohexane	63	300,000	300,000					
Hexane	53	500,000	50,000					
Heptane	41	500,000	85,000					
Bromomethane	11	-	-					
PEL and TLV values from NIOSH Pocket Guide to Chemical Hazards, June 1994								

**Table 6 (continues to next page)**  
**Dioxin, Dibenzofuran Air Sampling, BCDP Rapid Start (July 1995)**  
**Per-sample results and EPA "toxic equivalencies"**

SUBTOTALS picograms per sample	Test 1, Run-1	Test 1, Run-3	Test 1, Run-4				
	Test 1, Run 1	Test 1, Run 3	Test 1, Run 4	TEF, note (1)	Eq. Tox, Test 1, Run 1	Eq. Tox, Test 1, Run 3	Eq. Tox, Test 1, Run 4
TCDD	39	37	56				
PeCDD	190	140	170				
HxCDD	490	530	560				
HxCDF	310	140	160				
OCDD	480	120	220				
TCDF	38000	110000	42000				
PeCDF	53000	130000	86000				
HxCDF	13000	22000	20000				
HpCDF	660	1000	1200				
OCDF	23	35	36				
<b>Total, tetra through octachlorinated dioxins and dibenzofurans (all isomers), picograms per sample:</b>	<b>106,192</b>	<b>264,002</b>	<b>150,402</b>				
2,3,7,8-TCDD	14	9.1	5.8	1.0	14	9.1	5.8
1,2,3,7,8-PeCDD	39	46	56	0.5	19.5	23	28
1,2,3,4,7,8-HxCDD	29	55	52	0.1	2.9	5.5	5.2
1,2,3,6,7,8-HxCDD	40	38	37	0.1	4	3.8	3.7
1,2,3,7,8,9-HxCDD	22	27	11	0.1	2.2	2.7	1.1
1,2,3,4,6,7,8-HpCDD	160	68	92	0.01	1.6	0.68	0.92
OCDD	480	120	220	0.001	0.48	0.12	0.22
2,3,7,8-TCDF	10000	24000	12000	0.1	1000	2400	1200
1,2,3,7,8-PeCDF	6100	13000	10000	0.05	305	650	500
2,3,4,7,8-PeCDF	13000	22000	20000	0.5	6500	11000	10000
1,2,3,4,7,8-HxCDF	2600	3800	3600	0.1	260	380	360
1,2,3,6,7,8-HxCDF	1900	3500	3500	0.1	190	350	350
2,3,4,6,7,8-HxCDF	1300	2000	2000	0.1	130	200	200
1,2,3,7,8,9-HxCDF	250	500	520	0.1	25	50	52
1,2,3,4,6,7,8-HpCDF	510	890	880	0.01	5.1	8.9	8.8
1,2,3,4,7,8,9-HpCDF	25	48	67	0.01	0.25	0.48	0.67
OCDF	23	35	36	0.001	0.023	0.035	0.036
<b>TEQ pg per sample</b>					<b>8460</b>	<b>15084</b>	<b>12716</b>
<b>TEQ, ng per sample</b>					<b>8.46</b>	<b>15.08</b>	<b>12.72</b>
Notes:							
(1) TEF, "Toxic Equivalency Factors" taken from							
EPA proposed regulations for medical waste incinerators, 60 FR 10654, 27 Feb 1995							
(2) pg stands for picograms; ng for nanograms							
(3) Subtotals are given for all congeners of tetra-chloro-dibenzo-dioxin (TCDD), penta-chloro, (PCDD), etc							
(4) TEQ stands for Toxic Equivalency							
(5) When a compound was not detected, it was assumed present at the detection limit							

**Table 5, continued**  
**Dioxin, Dibenzofuran Air Sampling Results for BCDP Rapid Start (July 1995)**  
**(Sampling by Modified Method 23)**

Total Dioxins plus Furans	Volume sampled	stack flowrate	sampling duration	tons soil fed	Total Dioxin plus Furan conc.	Dioxin plus Furan emissions	Dioxin plus Furan emissions
pg/sample	dry std cu. ft.	dry std cfm	minutes		ng/cu. m	ng/hour	ng/ton soil
Test 1, Run 1	106,200	245.1	356	360	4.7	15.30	9255
Test 1, Run 3	264,000	178.4	219	301	3.4	52.25	19445
Test 1, Run 4	150,400	200	250	480	3.8	26.55	11280
<b>Average</b>						<b>31.37</b>	<b>13327</b>
Equiv. Tox. Dioxins and Furans	Volume sampled	stack flowrate measured	sampling duration	tons soil fed	Toxic Equivalent Conc., Dioxin plus Furan		
pg/sample	dry std cu. ft.	dry std cfm	minutes		nanograms per dry std. cubic meter		
Test 1, Run 1	8460	245.1	356	360	4.7	1.22	
Test 1, Run 3	15084	178.4	219	301	3.4	2.99	
Test 1, Run 4	12716	200	250	480	3.8	2.25	
<b>Average</b>						<b>2.15</b>	
pg stands for picograms; ng for nanograms							
<b>PROPOSED REGULATIONS, FOR COMPARISON</b>							
Regulation Proposed for:	Citation		Total Conc., ng/dscm	Toxic Equiv. Conc., ng/dscm			
Medical Waste incinerators	60 FR 10654, 27 Feb 1995		80	1.9			
Small Municipal Waste incinerators	59 FR 48228, 20 Sep 1995		60	1			
Large Municipal Waste incinerators	59 FR 48228, 20 Sep 1995		30	0.5			
Hazardous Waste incinerators	(unpublished)	N/A		2			

### **3.0 INTERPRETATION AND DISCUSSION**

Obtaining permits for remedial actions is generally not required at a site which is under jurisdiction of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). However, where permits would otherwise be required, the permit regulations would generally be considered “applicable and relevant requirements” (ARARs) under CERCLA. Thus while an actual permit may not be required, it is necessary to meet the substantive requirements which would apply. Air permitting of a thermal desorption unit like the BCDP unit is addressed by the Federal EPA although specific regulations have not yet been promulgated. Additionally, operation of the BCDP unit may come under additional state regulations when operated in some states. For example, in California, a site specific risk assessment under the “Air Toxics Hot Spots” law could be required. Such an analysis would rely on air dispersion modeling to estimate the amounts of contaminants to which people living or working near the unit would be exposed. Rather than take a risk assessment approach, we have selected relevant or related regulations for comparison to the measured emissions from the BCDP unit. These regulatory levels are discussed below.

#### **3.1 Polychlorinated Biphenyls**

As discussed in section 1.4, Sampling Rationale, the EPA is treating the air permitting of thermal desorption processes for remediation of PCB contaminated soil as if the units were incinerators. Toxic Substances Control Act (TSCA) regulations (40 CFR Part 761) require 99.9999% destruction of PCBs incinerated. This means that for those PCBs desorbed from the soil which must be captured by the BCDP air pollution control equipment, the standard is capture of 99.9999% of the PCBs desorbed. (This should not be confused with the standard applied to treatment of the soil itself, which is that the treated soil contain no more than 2 ppm of any given PCB congener.) Sampling and analysis of the soil fed during the air sampling periods performed by IT Corporation showed PCB concentrations consistently between 50 and 100 ppm during the rapid start runs. Details are included in Appendix F. Assuming 75 ppm PCBs in the soil fed, and assuming that essentially all PCBs fed are desorbed, the percentage capture of PCBs in the air pollution control equipment is approximately 99.998%, which approaches the required 99.9999%. It is anticipated that the percentage capture will meet or exceed the standard after installation of the additional control equipment. Also, it is likely that if a higher loading of PCBs were fed the percentage capture would be higher.

As mentioned above, some states will require a risk assessment based on air dispersion modeling. For example, the state of Washington Administrative Code, WAC 173-460, New Sources of Toxic Air Pollutants, provides an Acceptable Source Impact Level (ASIL) for PCB emissions of 0.0045 ug/m³ annual average, measured at the closest point of unrestricted public access. This corresponds to a Small Quantity Emission Rate (SQER) exemption value of 0.5 pounds/year. This is the quantity below which a new or modified source of PCB emissions would be exempt from state notification/permitting requirements. Since PCB emissions from the BCDP “rapid start” average approximately 770 micrograms per hour or 15 lbs per year of continuous operation, air dispersion modeling (and perhaps further action to satisfy permit requirements) would be required to operate the BCDP in Washington state with the rapid start emission controls.

### **3.2 Hydrochloric Acid**

Hydrochloric Acid can be produced when incineration or other thermal treatment is applied to chlorinated compounds. The EPA is applying the Resources Conservation and Recovery Act (RCRA) regulatory standard for incinerators to thermal desorbers. This standard is that HCl emissions shall not exceed 1.8 kilograms per hour. If emissions exceed 1.8 Kg/hr the emissions are still acceptable if the emissions control equipment captures 99% of the HCl produced. The BCDP equipment is emitting only about 15 grams of HCl per hour and is therefore acceptable.

### **3.3 Volatile Organic Contaminants**

Volatile organic compounds (VOCs) are not specifically addressed as individual constituents under incineration regulations. Sources of VOCs are regulated for general air pollution considerations, however, the amounts of VOCs emitted by the BCDP equipment would be considered minimal.

### **3.4 Particulate Matter**

The amounts of particulate matter emitted by the BCDP are minimal. Exact values could not be determined since the measured values were not significantly different from the level of error inferred from the blank (approximately 1 milligram per filter sample). Laboratory reports are included as Appendix C.

### **3.5 Dioxins and Dibenzofurans**

As discussed in Section 1.4, the EPA is not scheduled to address emissions standards for contaminated soil treatment facilities until the year 2000. However, the EPA has proposed regulations for various classes of incinerators. Medical waste incinerator and municipal waste incinerator proposed standards have been published in the Federal Register; hazardous waste incinerator standards have not yet been published but have been considered by the EPA. Dioxins and dibenzofurans are byproducts of incineration and are addressed by the incinerator standards. In an October 1995 telephone conversation with Hiroshi Dodahara, (202) 260-3959 (a U.S. EPA expert on PCB incineration, permitting), Mr. Dodahara indicated that the appropriate standard for comparison of thermal desorber emissions of dioxins and dibenzofurans would be the hazardous waste incinerator standard under consideration by the EPA. The unpublished standards under consideration are: 2 nanograms total dioxins and dibenzofurans (expressed as nanograms of toxic equivalency) per dry standard cubic meter of air emitted. The toxic equivalency is calculated using factors published by the EPA in the proposed regulations for other incinerators. Table 5 presents the dioxin and dibenzofuran results for the BCDP rapid start runs. Dioxin and dibenzofuran values converted to toxic equivalents, totaled, and averaged for three sampling runs are 2.15 nanograms per dry standard cubic meter. This value only slightly exceeds the 2 nanogram Toxic Equivalency limit for dioxins and dibenzofurans from hazardous waste incinerators, which is the most applicable currently available proposed regulatory standard available for comparison. It is anticipated that installation of the additional air pollution control equipment will further reduce dioxin and dibenzofuran emissions from the BCDP equipment.

## **APPENDIX F**

### **FULL SCALE SYSTEM STACK TEST REPORT SUMMARY**

**This summary is taken from: Saunders, Bob, et al., 1996, "BCDP Source Emission Test Result at Building 3009 Site Naval Station, Sumay, Guam," SSR-2243-ENV, Naval Facilities Engineering Service Center, Port Hueneme, California, August 1996.**

## 1.0 INTRODUCTION

This report provides results and documentation of air pollution source testing conducted by the Naval Facilities Engineering Service Center (NFESC) from 7 through 18 June 1996 on the Base Catalyzed Decomposition Process (BCDP) thermal desorber treating PCB contaminated soil at the Building 3009 Navy Installation Restoration site, Naval Station Sumay, Guam. This is the second series of air pollution source tests conducted after the scheduled installation of additional air pollution control equipment and the use of steam as the carrier gas, the increased capacity to full load condition of two tons per hour, and the thermal desorption of greater amounts of PCB laden soil. [NOTE: For the BCDP "Rapid Start" source emission test of July 1995, we assumed (based on analyses by IT Corp.) 75 ppm PCB in the feed soil to calculate the PCB removal percentage]. For the source emission test of June 1996, we used actual averaged values of PCB in mg/kg for each run to calculate the new BCDP thermal desorption PCB removal percentage. Actual averaged PCB concentrations were 2 to 3 times higher than the assumed "Rapid Start" value of 75 ppm.

Off gasses from the BCDP unit were tested for polychlorinated dibenzo-p-dioxins (PCDD's), polychlorinated dibenzofurans (PCDF's), polychlorinated biphenyls (PCBs), hydrogen chloride (HCl), semi-volatile organic compounds (Semi-VOC), volatile organic compounds (VOC), and particulate matter (PM). The purpose of the testing is to determine the stack outlet pollutant concentrations from the BCDP emission control equipment in order to provide necessary assurance that health and safety of nearby workers and residents is protected during operations. Additionally, knowledge of the emissions will be necessary for any future air permit applications which might be required for use of this equipment including the boiler and kiln burners at other sites. Off gas source emission analysis indicate that operation of the BCDP equipment does not pose a threat to the health and safety of workers or residents on Naval Station Sumay, Guam. The increased concentrations of volatile contaminants and carbon monoxide might pose a permitting problem for use of the equipment in some air pollution control jurisdictions.

## 1.1 REFERENCES

- (a) IT Corp. "TRANSITION PLAN" June 1993  
(PCB REMEDIAL ACTION, PWC, GUAM, M.I., Contract No. N47408 - 91 - D - 3043,  
Delivery Order 0009)
- (b) Site Specific Report (No.) SSR-2164-ENV, November 1995, BCDP "RAPID START" SOURCE  
EMISSION TEST RESULTS, BUILDING 3009 SITE, NAVAL STATION SUMAY, GUAM

## 1.2 SITE BACKGROUND

A brief history of the Building 3009 site is provided in reference (a). The Public Works Center (PWC) Building 3009 housed a transformer repair shop where electrical transformers were cleaned and repaired from approximately 1952 to 1977. The associated transformer oil storage and recycling system was removed from service in 1977 when leakage was identified. Although soils in the immediate vicinity of the oil storage and recycling system were removed and disposed of, several thousand tons of PCB contaminated soils and rock requiring treatment remain on site. The site soils are derived from coral rock and have little organic content below the uppermost soil horizon.

### 1.3 BCDP EQUIPMENT DESCRIPTION

The thermal desorber is an indirectly heated rotary reactor (kiln), fired on the kiln's outside barrel with fourteen oil fired burners. Note that the boiler, kiln burners, and the thermal desorption and dechlorination process inside the kiln result in air emissions, but the focus of this report is on the emissions from the BCDP process inside the kiln. If required for permitting purposes, emissions from the boiler and kiln burners can be estimated based on fuel consumption or steam output by the boiler. Table 1 furnishes the kiln's labelplate data. The kiln is rated for a maximum throughput of 2 tons of soil per hour. **Appendix D** provides data sheets for BCDP operation including kiln temperatures and feed rates for periods during the stack test runs. During the eight test runs, the kiln rotated within 0.85 and 1.77 revolutions per minute and processed between 1.86 and 2.00 tons of contaminated soil per hour (See Table 3. for kiln speed and feed rate average for each test run). Soil residence time in the kiln is on the order of one hour. Contaminated soil temperatures (from bed temperatures) averaged a minimum of 410.9 F at the front or kiln inlet to a maximum of 928.7 F at the back or kiln outlet. Treated soil "ash" exited the kiln outlet between 529.5 F to 602.6 F, and exhaust gasses exited the kiln (near the kiln inlet) between 378.7 F to 416.2 F.

The air pollution control equipment downstream of the kiln consisted of a steam purge at the kiln, multicyclone, wet electrostatic precipitator (WESP), condenser, chiller/condenser, high efficiency mist eliminator (HEME), and activated-carbon adsorption units, in that sequence.

As part of the Base Catalyzed Decomposition Process (BCDP), sodium bicarbonate is mixed with the soil before feeding to the kiln. Sodium bicarbonate was added to the soil feed at approximately 1% by weight. Sodium bicarbonate promotes partial dechlorination of PCBs in the kiln and is also thought to increase the effectiveness of the thermal desorption and decrease the formation of dioxins. Decomposition of sodium bicarbonate (baking soda) in the kiln contributes to carbon dioxide in the exhaust gas.

The kiln's steam purge, WESP, condenser, and chiller/condenser were not installed during the "Rapid Start" source emission test phase in July 1995 (see Reference (b) in Section 1.1). This series of source emission tests of June 1996 has the addition of a steam purge, WESP, condenser, and chiller/condenser and the reduced effect of the original venturi wet scrubber unit (off gas flows through the unit, but it is not operational except for water treatment to the unit's well). Some notable differences are discussed between the two series of test data in the following paragraph.

Steam is used to provide an inert sweep gas in the kiln - to reduce the free oxygen in the kiln and subsequent high temperature equipment (the ducting and cyclone). The intent of this was to discourage the formation of hazardous dioxin and furan compounds in the thermal desorption process. Although a mass balance addressing accumulation of material in the system was not performed, the dramatic ten-fold decrease in emissions of dioxins and dibenzofurans between the first and second sampling periods strongly suggests that using steam as the carrier gas does reduce dioxin and dibenzofuran formation. The use of steam also limits the air flow to the amount resulting from air leakage into the system: about 23 cfm during the testing. The result of this was a dramatic decrease in percent oxygen and dramatic increase in concentrations of carbon monoxide and volatile compounds in the exhaust gas. In addition to a concentration increase, the absolute amount of volatile compounds emitted appears to have increased beyond what is explainable from the heavier feed loading. Without the steam purge, average "Rapid Start" values for O₂, CO₂, and CO were 20.1%, 0.89%, and 322 ppm, respectively. With the steam

### 1.3 BCDP EQUIPMENT DESCRIPTION, continued

purge, average test values for O₂, CO₂, and CO were 8.5%, 16.51%, and greater than 1,000 ppm, respectively (concentrations of CO in the off-gas were above the analyzer's detection limit of 1000 ppm). Baking soda fed with soil decomposes in the kiln releasing additional CO₂ to the system. With reduced air flow, the CO₂ from this source is increased in relative importance as a percentage of the system off-gas.

TABLE 1: ROTARY KILN LABELPLATE DATA

Size/Type: 3'-0" Dia.x 38'-0" Lg. Rotary Calciner [6560-3]
Feed Rate: 2 Ton/Hr max.      Shell Speed: 0.5 to 5 R.P.M.
(Wet weight basis)              Screw Jacks: 21" Travel
Manufacture: Renneburg Division of Heyl and Patterson Inc.

### 1.4 SAMPLING RATIONALE

Under the 1990 amendments to the clean air act, the EPA is tasked with developing emission standards for a list of "toxic air contaminants." The standards will be specific to the processes producing the emissions and are to reflect the "Maximum Achievable Control Technology". Emission standards for contaminated soil treatment facilities are not likely to be addressed until the year 2000 (see Federal Register, Vol. 59, pp 66850, December 28, 1994). Given this regulatory uncertainty it was decided to sample and analyze for a range of volatile and semi-volatile organic contaminants with the goal of identifying what contaminants are emitted in significant amounts. Additionally, it was decided that sensitive analysis directed at quantifying emissions of PCBs, chlorinated dibenzo-para-dioxins, and chlorinated dibenzo furans, and HCl was appropriate. Dioxins and furans are products of any combustion or high temperature process where chlorine is present in the fuel. Hydrochloric acid (HCl), is also produced in combustion of chlorinated compounds. In April 1995, Hiroshi Dodahara, (202) 260-3959 (a U.S. EPA expert on PCB incineration, permitting), indicated that the EPA is treating thermal treatment units as they would an incinerator during trial testing. He indicated that the emissions from a non-incineration thermal PCB treatment unit should be tested for particulate matter (PM), hydrochloric acid (HCl), carbon dioxide (CO₂), oxygen (O₂), volatile organic compounds (VOC), and semi-volatile organic compounds (Semi-VOC) including PCBs, dioxins, and furans. The EPA may also require sampling for metals, if metals are present in the feed.

## **1.5 REFERENCES - AIR SAMPLING AND ANALYTICAL TEST METHODS**

Source emission test sampling procedures and equipment were in accordance with the U.S. Environmental Protection Agency (EPA) Test Methods (most are published in Title 40, Code of Federal Regulations, Part 60 (40 CFR 60), Appendix A). California Air Resources Board (CARB) Method 421 was used for HCl determination. The following EPA Test Methods describe test system train configurations and procedures used for stack gas testing. The Test Methods also describe procedures to be used by the laboratories for analyzing the sample pollutant concentrations:

- Method 1. Sample and Velocity Traverses for Stationary Sources.
- Method 1A. Sample and Velocity Traverses for Stationary Sources with Small Stacks or Ducts.
- Method 2C. Determination of Stack Gas Velocity and Volumetric Flow Rate in Small Stacks or Ducts (Standard Pitot Tube).
- Method 3A. Determination of Oxygen and Carbon Dioxide Concentrations in Emissions From Stationary Sources (Instrumental Analyzer Procedures).
- Method 4. Determination of Moisture Content in Stack Gases.
- Method 5. Determination of Particulate Emissions from Stationary Sources.
- Method 10. Determination of Carbon Monoxide Emissions From Stationary Sources.
- Method 23. Determination of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans From Stationary Sources.
- Method TO-14 Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using SUMMA Polished Canister Sampling and Gas Chromatographic (GCS) Analysis.
- Method 680 Analyze the extracts for PCBs using modified Method 680.

### **EPA Solid Waste Test Methods:**

#### **SW-846/**

- Method 0010 (Modified Method 5 Sampling Train) for polycyclic organic matter (POM).  
Determination of Destruction and Removal Efficiency (DRE) of semivolatile Organic Hazardous Compounds (POHCs) from incineration systems (PHS, 1967).
- Method 8100 Target Compounds.
- Method 8270 Analyze the sample for organic compounds.

### **State of California Air Resources Board, Stationary Source Test Methods:**

- Method 421 Determination of Gaseous Chloride and Fluoride In Emissions From Stationary Sources.

## 1.6 SOURCE EMISSION SAMPLING AND ANALYSIS PROCEDURES

Table 2 summarizes the analyte classes, sampling and analysis methods used.

TABLE 2: ANALYTE CLASSES, SAMPLING AND ANALYSIS METHODS

ANALYTE	SAMPLING METHOD	ANALYTICAL METHOD
Dioxins, Furans	40 CFR Part 60, Method 23	High resolution Gas Chromatography, High resolution Mass Spectrometry (HRGC/HRMS)
PCBs	SW-846, Method 0010	High resolution GCMS
Semi-Volatile Organic Compounds	SW-846, Method 0010	GCMS
Particulate Matter (PM) weight	40 CFR Part 60, Method 5	Gravimetric (weight) only
Volatile Organic Compounds (VOC)	EPA Method TO-14	Gas Chromatography, Mass Spectrometry
HCl	CARB Method 421	Ion Chromatography
Oxygen	40 CFR Part 60, Method 3A	On-line analysis (paramagnetic sensing)
Carbon monoxide	40 CFR Part 60, Method 3A	On-line analysis (infrared gas analysis)
Carbon dioxide	40 CFR Part 60, Method 3A	On-line analysis (infrared gas analysis)

The following presents a general overview of each test's equipment layout and procedures. Basically, exhaust gas is drawn from the stack and the contaminants are captured by some type of liquid, filter, or resin media, or captured in a container, for later analysis. All captured samples were shipped to a contract laboratory for analysis. Volatile organic contaminants (VOCs) were captured in an evacuated container (SUMA), as described below. Three VOC samples were taken. Sampling for other contaminants was performed in sets of three "runs" except for the PM where only two "runs" were performed.

Stack gas oxygen ( $O_2$ ), carbon dioxide ( $CO_2$ ), and carbon monoxide (CO) concentrations were analyzed immediately by on line instrumentation and readings recorded at timed sampling intervals, along with other data. Selections of the sampling entry point into the stack and the number and location of traverse points were in accordance with the requirements of EPA Method 1A (of 40 CFR Part 60). Since the stack diameter was 1.50 inches, we did not traverse the stack, but kept the train nozzle and standard pitot tube in the stack center throughout all test runs. The nozzle and standard pitot tube locations were greater than the preferred required equivalent stack diameters from all flow disturbances. This is an applicable EPA sampling method for small diameter stack's. Absence of cyclonic flow could not be verified per the procedure of EPA Method 1 because the standard pitot tube could not be rotated to the required perpendicular position to the off gas flow. Stack gas velocity, stack gas dry molecular weight, and moisture content were determined by EPA Methods 2, 3, and 4, respectively.

## 1.6 SOURCE EMISSION SAMPLING AND ANALYSIS PROCEDURES, continued

SUMA Canister: An evacuated 6 liter ultra clean stainless steel vacuum canister was used for drawing a sample of exhaust gas for volatile organic compound analysis. The lab analyzed the gas sample for 61 standard target compounds of Test Method TO-14, and monitored for the presence of other non-target "tentatively identified compounds."

Sample train 1 is composed of three separate measuring systems; (1) is for analyzing, on a continuous basis, CO₂, CO, and O₂, (2) is for measuring stack temperature, and (3) is for determination of stack gas velocity and volumetric flow rate.

System 1 draws a portion of flue gas from the stack through tubing to the analyzers using a pump as the conveyor. Moisture is removed from the flue gas by condensing with an ice bath and collecting the water in a knockout trap. The flue gas is further polished of moisture by drawing it through a canister of "drierite" and then filtered for any particulate before it enters the pump. From the pump, the flue gas is pushed into a manifold from which it is distributed to each analyzer at a rate of 0.5 l/m. CO₂/CO is measured with a California Analytical Instrument (FUGI model ZRH) with non-dispersive and infrared gas analysis. O₂ is measured with a Servomex model 570A with paramagnetic sensing.

System 2 is a thermocouple attached to a digital readout.

System 3 is a standard pitot tube (coefficient of 0.99) connected to a 0-10 in. H₂O manometer with 0.1 in. H₂O increments.

Sample train 2 used modifications of Methods 5 and 23 and was used to test for HCl, semivolatiles (Semi-VOC), PCB, PM, Chlorinated Dibenzo Furans and Chlorinated Dibenzo Dioxins.

The outlet pollutant concentration of an analyte is determined by standard testing methods and procedures. Stack testing methods and procedures for off gases are mostly achieved by performing source emission tests. The goal of source testing is to quantitatively draw the off gas from a stack through a sampling train. Typical stack sampling trains for toxic analyte classes such as Dioxins/Furans consist of a probe with nozzle and liner, a glass fiber filter (in a filter holder), connecting tubing or line, a cooling coil or condenser, a XAD resin trap and impingers. The dioxins/furans are trapped in the filter, the XAD resin, or can stick to the walls of the probe, filter holder, tubing, or cooling coil. In order to collect all of the dioxins and furans, the nozzle, probe liner, filter holder inlet, frit, filter holder outlet, teflon line, and cooling coil interior surfaces are rinsed with solvent and the solvent collected as part of the sample (along with the filter and the XAD trap). In the standard Method 23 (for dioxins/furans), these various train parts are rinsed three times with acetone followed by three rinses of toluene. The rinses are collected, evaporated to a concentration less than 30ml (due to international air transportation dangerous goods regulations), transferred to sample containers, and cold shipped in coolers along with the filters and traps directly to laboratories for analysis.

PM tests followed EPA Method 5 procedures with the front-half of the sampling train (nozzle, probe liner, and filter holder inlet) rinsed three times with acetone. The rinses and filter are weighed with the result being one of the variables for the particulate emission equation.

TABLE 4: STACK GAS SAMPLING DATA  
BCDP, NAVAL STATION SUMAY, GUAM, MARIANA ISLANDS

BUILDING 3009 SITE

DATE	SAMPLE I.D. (Test/Run)	O ₂ %	CO ₂ %	H ₂ O %	Avg. STACK TEMP. (deg. F)	Avg. STACK VELOCITY (fps)	ACTUAL STACK FLOW (acfmin)	TOTAL TEST TIME (min.)	VOL. OF OFF GAS SAMPLED (dscfm)	DRY STD. STACK FLOW (dscfm)	PERCENT ISOKINETIC (%)
6/7/96	1/1	9.5	15.62	1.6	97.2	29.61	22	480	340.74	20	100.5
6/9/96	1/2	9.1	14.47	1.7	101.6	33.83	25	360	296.30	23	103.1
6/11/96	1/3	7.6	17.30	5.7	99.9	30.36	22	360	242.16	20	113.1
AVERAGE TEST 1 >>		8.7	15.80	3.0	99.6	31.27	23			21	

6/13/96	2/1	8.3	15.45	4.6	101.6	42.60	31	360	307.78	28	101.4
6/16/96	2/2	8.6	17.19	4.1	96.5	29.45	22	450	252.80	20	95.0
6/18/96	2/3	8.7	15.99	2.4	91.3	28.67	21	450	252.65	20	108.6
AVERAGE TEST 1 >>		8.5	16.21	3.7	96.5	33.57	25			23	

6/17/96	3/1	8.3	17.78	3.5	97.1	28.36	21	60	37.29	19	108.7
6/17/96	3/2	8.1	17.27	2.0	88.7	29.61	22	60	45.35	21	105.7
AVERAGE TEST 1 >>		8.2	17.53	2.8	92.9	28.99	22			20	

## 1.7 SOURCE EMISSION SAMPLING TEST SCHEDULE

Table 3 displays source emission stack outlet test schedule with kiln speed, feed rate, and bed, ash and off gas outlet temperature information for each test run. Table 4 displays stack gas sampling data such as stack velocity and temperature.

**TABLE 3: SOURCE EMISSION STACK OUTLET TEST SCHEDULE  
WITH KILN SPEED, FEED RATE, AND  
BED, ASH AND OFF GAS OUTLET TEMPERATURE INFORMATION FOR EACH TEST RUN**

DATE	LINE PROCESS	TEST/RUN	START TIME (approx.)	TOTAL TEST TIME (minutes)	KILN R.P.M. (avg.)	KILN FEED (avg. tons of soil fed/hr)	BED TEMP. MIN. (avg. F.)	BED TEMP. MAX. (avg. F.)	ASH TEMP. (avg. F.)	KILN TEMP. [OFF GAS OUT] (avg. F.)
6/7/96	DIOXIN/FURAN	1/1	0830	480	1.3755	1.902	410.9	908.4	545.4	416.2
6/9/96	DIOXIN/FURAN	1/2	0925	360	1.54	1.86	452.6	915.0	559.5	403.5
6/10/96	VOLATILES (1)	-	<5	-	-	-	-	-	-	-
6/11/96	DIOXIN/FURAN	1/3	0800	360	1.77	1.86	441.8	867.8	529.5	378.7
6/11/96	DIOXIN/FURAN	1/3-Blank	0855	N/A	N/A	N/A	N/A	N/A	N/A	N/A
6/13/96	SEMIVOC/PCB	2/1	0917	360	0.96	1.94	562.2	928.7	602.6	409.8
6/16/96	HCL/SEMIVOC/PCB	2/2	0927	450	1.67	1.95	486.5	886.9	557.7	387.5
6/17/96	PM	3/1	1713	60	0.85	1.97	492.4	886.3	553.9	392.4
6/17/96	PM	3/2	2025	60	1.53	2.00	508.8	858.3	548.3	395.9
6/18/96	SEMIVOC/PCB	2/3	1305	450	1.20	1.94	472.2	822.2	541.9	406.7
6/18/96	SEMIVOC/PCB	2/3-Blank	1405	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7/3/96	VOLATILES (2)	-	?	-	-	-	-	-	-	-
7/3/96	VOLATILES (3)	-	?	-	-	-	-	-	-	-

Note: Volatiles are captured by using SUMA canisters; all other processes are collected by using a modified version of EPA Method 5 (source emission tests).

Volatiles test 2 and 3 were performed by IT Corp. personnel. Date test was performed is approximate.

## **2.0 INTERPRETATION AND DISCUSSION**

Obtaining permits for remedial actions is generally not required at a site which is under jurisdiction of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). However, where permits would otherwise be required, the permit regulations would generally be considered “applicable and relevant requirements” (ARARs) under CERCLA. Thus while an actual permit may not be required, it is necessary to meet the substantive requirements that would apply. Air permitting of a thermal desorption unit like the BCDP unit is addressed by the Federal EPA although specific regulations have not yet been promulgated. Additionally, operation of the BCDP unit may come under additional state regulations when operated in some states. For example, in California, a site specific risk assessment under the “Air Toxics Hot Spots” law could be required. Such an analysis would rely on air dispersion modeling to estimate the amounts of contaminants to which people living or working near the unit would be exposed. Rather than take a risk assessment approach, we have selected relevant or related regulations for comparison to the measured emissions from the BCDP unit. These regulatory levels are discussed below.

### **2.1 Polychlorinated Biphenyls**

As discussed in section 1.4, Sampling Rationale, the EPA is treating the air permitting of thermal desorption processes for remediation of PCB contaminated soil as if the units were incinerators. Toxic Substances Control Act (TSCA) regulations (40 CFR Part 761) require 99.9999% destruction of PCBs incinerated. This means that for those PCBs desorbed from the soil which must be captured by the BCDP air pollution control equipment, the standard is capture of 99.9999% of the PCBs desorbed. (This should not be confused with the standard applied to treatment of the soil itself, which is that the treated soil contain no more than 2 ppm of any given PCB congener.) Table 5 shows BCDP PCB percent removal greater than 99.9999%. Sampling and analysis of the soil fed during the air sampling periods was performed by IT Corporation. PCB results for feed soil are shown in Appendix E and are included in calculations on Table 5.

As mentioned above, some states will require a risk assessment based on air dispersion modeling. For example, the state of Washington Administrative Code, WAC 173-460, New Sources of Toxic Air Pollutants, provides an Acceptable Source Impact Level (ASIL) for PCB emissions of 0.0045 ug/m³ annual average, measured at the closest point of unrestricted public access. This corresponds to a Small Quantity Emission Rate (SQER) exemption value of 0.5 pounds/year. This is the quantity below which a new or modified source of PCB emissions would be exempt from state notification/permitting requirements. PCB emissions from the BCDP average approximately 120 micrograms per hour or 0.00231 lbs per year of continuous operation. This would more than meet the State’s requirements.

### **2.2 Hydrochloric Acid**

Hydrochloric Acid can be produced when incineration or other thermal treatment is applied to chlorinated compounds. The EPA is applying the Resources Conservation and Recovery Act (RCRA) regulatory standard for incinerators to thermal desorbers. This standard is that HCl emissions shall not exceed 1.8 kilograms per hour. If emissions exceed 1.8 Kg/hr the emissions are

## **2.0 INTERPRETATION AND DISCUSSION, continued**

still acceptable if the emissions control equipment captures 99% of the HCl produced. Table 5 shows the BCDP equipment is emitting only about 1.5 grams of HCl per hour and is therefore acceptable.

### **2.3 Semivolatile Organic Contaminants**

Semivolatile organic compounds (Semi-VOCs) are not specifically addressed as individual constituents under incineration regulations. The lab analyzed the gas sample for 64 standard target compounds. Sources of Semi-VOCs are regulated for general air pollution considerations, however, the amounts of Semi-VOCs emitted by the BCDP equipment would be considered minimal (see Table 5 for compounds over non-detect limits).

### **2.4 Dioxins and Dibenzofurans**

As discussed in Section 1.4, the EPA is not scheduled to address emissions standards for contaminated soil treatment facilities until the year 2000. However, the EPA has proposed regulations for various classes of incinerators. Medical waste incinerator and municipal waste incinerator proposed standards have been published in the Federal Register; hazardous waste incinerator standards have not yet been published but have been considered by the EPA. Dioxins and dibenzofurans are byproducts of incineration and are addressed by the incinerator standards. In October 1995, Hiroshi Dodahara, (202) 260-3959 (a U.S. EPA expert on PCB incineration, permitting), indicated that the appropriate standard for comparison of thermal desorber emissions of dioxins and dibenzofurans would be the hazardous waste incinerator standard under consideration by the EPA. The proposed standards for hazardous waste incinerators are 0.2 nanograms dioxins and dibenzofurans (expressed as nanograms of toxic equivalency) per dry standard cubic meter of air emitted. The toxic equivalency is calculated using factors published by the EPA. Table 6 presents the dioxin and dibenzofuran results for the BCDP test runs. Dioxin and dibenzofuran values converted to toxic equivalents, totaled, and averaged for three sampling runs are 0.18 nanograms per dry standard cubic meter. This value is below the 0.2 nanogram Toxic Equivalency limit for dioxins and dibenzofurans from hazardous waste incinerators, which is the most applicable currently available proposed regulatory standard available for comparison.

### **2.5 Volatile Organic Contaminants**

The lab analyzed the SUMA canister gas samples for 61 standard target compounds and monitored for the presence of other non-target "tentatively identified compounds." The result of the analysis found heavy increases of volatile compounds in the exhaust gas compared to the previous "Rapid Start" test analysis of last year. Among the compounds were toxic air contaminants. These compounds would trigger a Toxic New Source Review, a Health Risk Assessment, before the unit could be operated in California. What other states would do depends on their specific needs and requirements. Under current federal incineration regulations, volatile compounds are not specifically addressed as individual constituents.

## 2.0 INTERPRETATION AND DISCUSSION, continued

### 2.6 Particulate Matter

The amounts of particulate matter from the off gas emitted by the BCDP appear to be insignificant. Exact amounts of total particulate could not be determined; results provided by the lab appear questionable. As an example; The solution used to rinse the front half of the Method 5 train is the same solution from the same container as the acetone rinse blank sample. Yet, the acetone rinse blank amount was greater than the total particulate weight of the front half rinse. Laboratory reports are included as Appendix C.

**Table 5**  
**PCB, HCl, and SEMI-VOC Stack Sampling Results for BCDP Source Emission Test Runs**

PCB									
	Tot. PCB Compound (OUT)	Volume (off gas) sampled	Stack Flowrate (dry)	Sampling Duration	avg. tons of soil fed	avg. PCB in feed soil (IN)	PCB density conc.	PCB emissions	PCB % removal
Test/Run	tot. ng. conc./ sample	dscf	dscfm	minutes	tons / hour	mg / kg	microgr/ cu. m.	microgr/ hr.	
2/1	49159	307.78	28	360	1.94	217	5.64	268	99.99993
2/2 *	11374	252.80	20	450	1.95	210	1.59	54	99.99999
2/3	7766	252.65	20	450	1.94	123	1.09	37	99.99998
Average	22766	271.08	23				2.77	119.74	100.0000
* - High Efficiency Mist Eliminator (HEME) filter changed between PCB Run 1 and PCB Run 2.									
HCl									
	Total HCl	Volume (off gas) sampled	Stack Flowrate (dry)	Sampling Duration	tons soil fed	HCl density conc.	HCl emission		
Test/Run	micrograms	dscf	dscfm	minutes		mg / cu. m.	mg / hr.		
2/2	310	252.80	20	450	14.6	0.043	1.5		
Carbon Monoxide was above the analyzer's detection limit of 1000 ppm during sampling; (field data in Appendix B).									
SEMIVOLATILE									
The following semivolatile contaminants were detected from the lab analysis (see lab analysis in Appendix C):									
TEST 2	RUN								
	1	2	3	BLANK					
Contaminant	Amount microgram per sample	grams/hr	kg/yr						
bis(2-Ethylhexyl)phthalate	370 E	9.6	ND	7.6					
Nitrobenzene	17	4.1	36	ND	0.10	0.84			
Diethylphthalate	2.3	2.9	ND	ND					
Di-n-Octylphthalate	4.2	ND	ND	ND					
ND - Not Detected (see Appendix C for actual detection limit values).									
E - Exceeds instrument calibration range, but within linear range.									
Blank run and run 3 performed simultaneously.									

**Table 6 (continues to next page)**  
**Dioxin, Dibenzofuran Stack Sampling Results BCDP Source Emission Test Runs**  
**(Per-sample results and EPA "toxic equivalencies")**

SUBTOTALS picograms per sample	Test 1, Run-1	Test 1, Run 2	Test 1, Run 3				
TCDD	370	470	260				
PeCDD	360	470	270				
HxCDD	430	450	320				
HpCDD	120	130	120				
OCDD	110	76	78				
TCDF	17000	19000	14000				
PeCDF	10000	11000	8700				
HxCDF	2000	2100	1600				
HpCDF	110	110	94				
OCDF	8.8	6.8	5.8				
<b>Total, tetra through octa-chlorinated dioxins and dibenzofurans (all isomers), picograms per sample:</b>	<b>30,509</b>	<b>33,813</b>	<b>25,448</b>				
	Test 1, Run 1	Test 1, Run 2	Test 1, Run 3	TEF, note (1)	Eq. Tox, Test 1, Run 1	Eq. Tox, Test 1, Run 2	Eq. Tox, Test 1, Run 3
2,3,7,8-TCDD	8.6	11	7.3	1.0	8.6	11	7.3
1,2,3,7,8-PeCDD	27	32	20	0.5	13.5	16	10
1,2,3,4,7,8-HxCDD	17	18	13	0.1	1.7	1.8	1.3
1,2,3,6,7,8-HxCDD	21	24	19	0.1	2.1	2.4	1.9
1,2,3,7,8,9-HxCDD	22	24	19	0.1	2.2	2.4	1.9
1,2,3,4,6,7,8-HpCDD	49	56	53	0.01	0.49	0.56	0.53
OCDD	110	76	78	0.001	0.11	0.076	0.078
2,3,7,8-TCDF	4000	4500	3300	0.1	400	450	330
1,2,3,7,8-PeCDF	1000	1100	770	0.05	50	55	38.5
2,3,4,7,8-PeCDF	2200	2000	1600	0.5	1100	1000	800
1,2,3,4,7,8-HxCDF	330	340	240	0.1	33	34	24
1,2,3,6,7,8-HxCDF	310	310	230	0.1	31	31	23
2,3,4,6,7,8-HxCDF	190	170	120	0.1	19	17	12
1,2,3,7,8,9-HxCDF	33	32	24	0.1	3.3	3.2	2.4
1,2,3,4,6,7,8-HpCDF	80	78	71	0.01	0.8	0.78	0.71
1,2,3,4,7,8,9-HpCDF	6.5	7.2	6	0.01	0.065	0.072	0.06
OCDF	8.8	6.8	5.8	0.001	0.0088	0.0068	0.0058
TEQ pg per sample					1666	1625	1254
TEQ, ng per sample					1.67	1.63	1.25
Notes:							
(1) TEF, "Toxic Equivalency Factors" taken from							
EPA proposed regulations for medical waste incinerators, 60 FR 10654, 27 Feb 1995							
(2) pg stands for picograms; ng for nanograms							
(3) Subtotals are given for all congeners of tetra-chloro-dibenzo-dioxin (TCDD), penta-chloro, (PCDD), etc							
(4) TEQ stands for Toxic Equivalency							
(5) When a compound was not detected, it was assumed present at the detection limit							

**Table 6, continued**

## **Dioxin, Dibenzofuran Stack Sampling Results for BCDP Source Emission Test Runs (Sampling by Modified Method 23)**

**Table 7**  
**VOC and PM Stack Sampling Results for BCDP Source Emission Test Runs**

VOC									
The following volatile contaminants were detected in each of three SUMA cannister grab samples:									
SUMA Cannister Grab Sample No.									
1      2      3									
Contaminant	ppm volumetric	ppm volumetric	ppm volumetric	ppm average	for relative comparison, OSHA PEL, ppm	NIOSH TLV, ppm	mw	gm/hr	kg/yr
Propylene	1300	760 E	770	943	-	-	42	63.3	554.1
Acetone	2400 E *	70	94	82	1,000	250	58.1	7.6	66.7
Benzene	78	82	110	90	1	0	78.1	11.2	98.4
Chloromethane	77	34	38	50	350	350	50.5	4.0	35.1
2-Butanone (MEK)	23	42	48	38	200	200	72.1	4.3	38.0
Heptane	ND	10	34	22	500	85	100.2	3.5	30.8
Bromomethane	5.5	3.9	ND	5	20	Ca	95.0	0.7	6.2
Toluene	9.9	200	230	147	200	100	92.1	21.6	188.9
others	363	590	667	540					
ND - Not Detected (see Appendix C for actual detection limit values).									
Ca - Potential Occupational Carcinogen; Threshold Limit Not Identified.									
E - Exceeds instrument calibration range, but within linear range.									
* - Acetone contaminant compound from SUMA Cannister Grab Sample No. 1 should be voided.									
SUMA sampling probe line was cleaned with acetone prior to drawing an "off gas" sample from the stack.									
Acetone may not have completely evaporated from the probe before we sampled stack.									
Benzene is above the PEL and TVL limit.									
PEL and TVL values from NIOSH Pocket Guide to Chemical Hazards, June 1994									
PM									
Test/Run	Total Particulate (mG)	dscf	Lbs/dscf	dscf/min.	Lbs/hr	Lbs/yr			
2/1	5.1	37.29	3.02E-07	19	3.44E-04	3.01			
2/2 *	5.1	45.35	2.48E-07	21	3.12E-04	2.74			

## **APPENDIX G**

### **PCB ANALYTICAL DATA FOR RAW AND PROCESSED SOIL**

Table G-1  
Rapid Start Daily Composite Average Total PCB in the Feed Soil and Reactor Product

Feed Soil			
Date	PPM PCB	Date	PPM PCB
7/12/95	74	8/8/95	30
7/14/95	135	8/9/95	39
7/15/95	130	8/9/95	68
7/15/95	57	8/9/95	66
7/15/95	72	8/10/95	82
7/16/95	52	8/10/95	53
7/16/95	100	8/10/95	79
7/16/95	67	8/11/95	4
7/17/95	130	8/11/95	35
7/29/95	50	8/11/95	110
7/29/95	69	8/11/95	53
7/30/95	30	8/11/95	51
7/30/95	74	8/11/95	110
7/30/95	100	8/11/95	43
7/31/95	33	8/14/95	33
8/1/95	50	8/14/95	60
8/1/95	55	8/15/95	46
8/1/95	50	8/15/95	27
8/2/95	53	8/15/95	16
8/2/95	68	8/19/95	16
8/3/95	91	8/19/95	5
8/4/95	83	8/19/95	19
8/4/95	44	8/19/95	11
8/5/95	36	8/19/95	2
8/5/95	65	8/21/95	4.5
8/6/95	42	8/21/95	10
8/6/95	54	8/22/95	33
8/6/95	97	8/22/95	9
8/7/95	50	8/22/95	30
8/8/95	68	8/23/95	2
8/8/95	34		

Reactor Product			
Date	PPM PCB	Date	PPM PCB
7/12/95	< 2	8/9/95	< 2
7/12/95	< 2	8/10/95	< 2
7/12/95	< 2	8/10/95	< 2
7/12/95	6	8/10/95	< 2
7/14/95	< 2	8/11/95	< 2
7/15/95	< 2	8/11/95	< 2
7/15/95	< 2	8/11/95	< 2
7/15/95	< 2	8/12/95	< 2
7/16/95	< 2	8/12/95	< 2
7/16/95	< 2	8/12/95	< 2
7/16/95	< 2	8/13/95	< 2
7/17/95	< 2	8/14/95	< 2
7/29/95	< 2	8/14/95	< 2
7/29/95	4	8/15/95	< 2
7/30/95	4	8/15/95	< 2
7/30/95	7	8/15/95	< 2
7/30/95	< 2	8/19/95	< 2
7/31/95	< 2	8/19/95	< 2
7/31/95	< 2	8/20/95	< 2
8/1/95	< 2	8/20/95	< 2
8/1/95	< 2	8/21/95	< 2
8/1/95	< 2	8/21/95	< 2
8/2/95	< 2	8/22/95	< 2
8/2/95	< 2	8/22/95	< 2
8/3/95	< 2	8/22/95	< 2
8/4/95	3	8/23/95	< 2
8/6/95	< 2		
8/6/95	< 2		
8/6/95	< 2		
8/9/95	< 2		
8/9/95	< 2		

**Table G-2**  
**Daily Composite Feed Soil Total PCB Content (in ppm) During Full Scale Operation**  
**(Page 1 of 3)**

Date	PPM PCB	Date	PPM PCB	Date	PPM PCB	Date	PPM PCB
2/5/96	63	4/6/96	140	5/16/96	110	6/26/96	160
2/8/96	320	4/8/96	99	5/17/96	100	6/28/96	76
2/16/96	67	4/8/96	110	5/18/96	52	6/28/96	105
2/17/96	140	4/9/96	71	5/20/96	120	6/29/96	79
2/18/96	55	4/10/96	76	5/20/96	120	7/1/96	96
2/19/96	50	4/11/96	77	5/21/96	68	7/1/96	84
2/20/96	75	4/12/96	98	5/22/96	84	7/3/96	120
2/21/96	37	4/13/96	91	5/24/96	100	7/3/96	150
2/22/96	110	4/15/96	90	5/24/96	100	7/6/96	88
2/23/96	64	4/15/96	110	5/25/96	56	7/6/96	86
2/25/96	150	4/16/96	85	5/27/96	44	7/6/96	60
2/26/96	110	4/17/96	68	5/27/96	44	7/8/96	68
2/27/96	120	4/19/96	55	5/28/96	68	7/8/96	74
2/28/96	86	4/20/96	56	6/1/96	17	7/10/96	78
2/29/96	68	4/22/96	34	6/3/96	44	7/10/96	71
3/1/96	120	4/22/96	100	6/3/96	52	7/16/96	61
3/2/96	350	4/23/96	100	6/5/96	88	7/16/96	540
3/3/96	140	4/24/96	120	6/5/96	80	7/20/96	210
3/4/96	250	4/25/96	92	6/7/96	84	7/20/96	220
3/5/96	180	4/26/96	100	6/7/96	72	7/20/96	230
3/6/96	170	4/28/96	64	6/8/96	72	7/22/96	200
3/22/96	150	4/28/96	100	6/11/96	110	7/22/96	330
3/26/96	110	4/29/96	85	6/11/96	120	7/23/96	560
3/27/96	95	5/4/96	250	6/12/96	170	7/27/96	430
3/23/96	180	5/6/96	150	6/14/96	170	7/27/96	490
3/25/96	120	5/4/96	350	6/14/96	160	7/27/96	690
3/25/96	140	5/7/96	130	6/17/96	180	7/27/96	450
3/28/96	130	5/8/96	140	6/18/96	150	7/30/96	300
3/29/96	100	5/9/96	140	6/18/96	160	7/30/96	140
3/30/96	70	5/11/96	250	6/20/96	200	7/30/96	300
4/1/96	120	5/11/96	480	6/20/96	140	7/31/96	470
4/1/96	140	5/13/96	520	6/24/96	94	8/3/96	400
4/2/96	160	5/13/96	110	6/24/96	89	8/3/96	340
4/3/96	120	5/14/96	96	6/24/96	99	8/3/96	370
4/5/96	120	5/16/96	210	6/26/96	220	8/5/96	590

**Table G-2**  
**Daily Composite Feed Soil Total PCB Content (in ppm) During Full Scale Operation**  
**(Page 2 of 3)**

Date	PPM PCB	Date	PPM PCB	Date	PPM PCB	Date	PPM PCB
8/5/96	610	9/13/96	310	10/29/96	230	12/19/96	290
8/7/96	250	9/17/96	260	10/29/96	220	12/23/96	280
8/7/96	280	9/17/96	290	10/29/96	230	12/23/96	260
8/11/96	1000	9/17/96	200	10/29/96	220	12/23/96	250
8/11/96	710	9/20/96	220	10/29/96	270	12/23/96	410
8/11/96	970	9/20/96	190	10/31/96	230	12/26/96	310
8/11/96	490	9/20/96	170	10/31/96	200	12/26/96	340
8/12/96	480	9/27/96	83	11/4/96	220	12/26/96	240
8/16/96	1200	9/27/96	55	11/4/96	200	12/28/96	280
8/16/96	560	9/27/96	25	11/4/96	140	12/28/96	180
8/16/96	320	10/1/96	38	11/4/96	95	1/1/97	170
8/16/96	380	10/1/96	23	11/12/96	190	1/1/97	220
8/18/96	400	10/04/96	36	11/12/96	280	1/1/97	140
8/18/96	290	10/04/96	17	11/12/96	250	1/4/97	180
8/20/96	360	10/04/96	18	11/30/96	250	1/4/97	190
8/20/96	520	10/08/96	53	11/30/96	190	1/4/97	190
8/23/96	360	10/08/96	230	11/30/96	130	1/6/97	200
8/23/96	190	10/08/96	260	11/30/96	78	1/6/97	150
8/23/96	190	10/08/96	320	12/3/96	12	1/6/97	140
8/25/96	370	10/10/96	340	12/3/96	49	1/9/97	240
8/25/96	230	10/10/96	290	12/3/96	77	1/9/97	290
8/28/96	300	10/14/96	170	12/6/96	260	1/9/97	270
8/28/96	310	10/14/96	200	12/6/96	300	1/10/97	290
8/28/96	300	10/14/96	49	12/6/96	340	1/13/97	260
8/31/96	210	10/14/96	150	12/9/96	380	1/13/97	290
8/31/96	260	10/15/96	200	12/9/96	360	1/13/97	290
8/31/96	190	10/18/96	230	12/9/96	450	1/16/97	250
9/03/96	320	10/18/96	60	12/13/96	360	1/16/97	310
9/03/96	320	10/18/96	32	12/13/96	380	1/16/97	320
9/09/96	310	10/21/96	32	12/13/96	350	1/20/97	300
9/09/96	330	10/21/96	28	12/13/96	340	1/20/97	340
9/10/96	340	10/21/96	190	12/16/96	300	1/20/97	360
9/10/96	290	10/23/96	260	12/16/96	330	1/20/97	410
9/13/96	350	10/23/96	260	12/16/96	360	1/23/97	260
9/13/96	290	10/29/96	260	12/19/96	310	1/23/97	290

**Table G-2**  
**Daily Composite Feed Soil Total PCB Content (in ppm) During Full Scale Operation**  
**(Page 3 of 3)**

Date	PPM PCB	Date	PPM PCB	Date	PPM PCB
1/23/97	230	3/2/97	1100	4/07/97	370
1/25/97	77	3/2/97	1200	4/07/97	520
1/25/97	120	3/6/97	790	4/15/97	340
1/30/97	57	3/6/97	770	4/15/97	110
1/30/97	120	3/6/97	890	4/15/97	190
1/30/97	210	3/6/97	890	4/15/97	310
1/30/97	230	3/10/97	1400	4/21/97	150
2/3/97	320	3/10/97	1400	4/21/97	110
2/3/97	340	3/10/97	1300	4/21/97	130
2/3/97	280	3/10/97	1100	4/21/97	200
2/3/97	170	3/13/97	340	4/24/97	330
2/6/97	170	3/13/97	190	4/24/97	240
2/6/97	190	3/13/97	450	4/24/97	180
2/6/97	170	3/13/97	220	4/24/97	130
2/10/97	130	3/18/97	330	4/28/97	240
2/10/97	150	3/18/97	290	4/28/97	340
2/11/97	120	3/18/97	450	4/28/97	260
2/11/97	150	3/18/97	600	4/30/97	320
2/11/97	190	3/20/97	380	4/30/97	260
2/15/97	95	3/20/97	430	4/30/97	260
2/15/97	100	3/20/97	470	5/01/97	260
2/15/97	160	3/20/97	520	5/05/97	170
2/15/97	150	3/25/97	440	5/05/97	200
2/17/97	97	3/25/97	400	5/05/97	180
2/17/97	120	3/25/97	630	5/05/97	220
2/20/97	150	3/25/97	590	5/07/97	220
2/20/97	220	3/30/97	410	5/07/97	180
2/20/97	240	3/30/97	490		
2/22/97	140	3/30/97	410		
2/22/97	200	3/30/97	930		
2/26/97	200	4/02/97	770		
2/26/97	200	4/02/97	630		
2/26/97	270	4/02/97	670		
3/2/97	670	4/07/97	170		
3/2/97	950	4/07/97	480		

Table G-3  
Daily Composite Reactor Product Total PCB Content (in ppm) During Full Scale Operation

Date	Bin	PPM PCB	Date	Bin	PPM PCB
2/15/96	BIN-B 2/14	17	3/3/96	BIN-B -3/2-3/3	11
2/16/96	BIN-A 2/15	24	3/4/96	BIN-A 3/3	6.3
2/17/96	BIN-B 2/16	26	3/4/96	BIN-B -3/4	6.8
2/18/96	BIN-A 2/17	16	3/5/96	BIN-A -3/4-3/5	ND (2)
2/18/96	BIN-B 2/17-2/18	0.71	3/6/96	BIN-B -3/5-3/6	ND (2)
2/19/96	BIN-A 2/18-2/19	1.5	3/23/96	BIN-A 3/21-3/22	1.4
2/20/96	BIN-B -2/19	0.65	3/23/96	BIN-B 3/22-3/23	1.3
2/20/96	BIN-A -2/20	2.2	3/25/96	BIN-B 3/23-3/24	14
2/21/96	BIN-B -2/20-2/21	1	3/27/96	BIN-A 3/24-3/25	41
2/22/96	BIN-A -2/21-2/22	1.1	3/27/96	GRAB-B 3/27	65
2/22/96	BIN-B -2/22	1.3	3/28/96	BIN-B 3/26-3/27	38
2/23/96	BIN-A -2/22-2/23	1.4	3/28/96	BIN-C 1.5 TPH	28
2/23/96	BIN-B -2/23	1.2	3/29/96	BIN-C 3/27-3/28	23
2/24/96	BIN-A -2/23-2/24	1.7	3/30/96	BIN-A 3/28-3/29	49
2/24/96	BIN-B -2/24	3.1	4/1/96	BIN-B 3/29-3/30	17
2/25/96	BIN-B -2/25	1.8	4/2/96	BIN-C 3/31-4/1	12
2/25/96	BIN-A -2/24-2/25	2.7	4/3/96	BIN-A 4/1-4/3	ND (1)
2/26/96	BIN-A -2/26	0.63	4/4/96	BIN-A 4/3-4/4	1.8
2/27/96	BIN-B -2/26-2/27	0.85	4/6/96	BIN-C 4/4-4/6	1.5
2/28/96	BIN-A -2/27-2/28	1.8	4/8/96	BIN-A 4/6-4/8	1.3
2/28/96	BIN-B -2/28	3.7	4/9/96	BIN-B 4/8-4/9	ND (0.5)
2/29/96	BIN-A -2/28-2/29	3	4/11/96	BIN-C 4/9-4/11	1.3
2/29/96	BIN-B -2/29	8.8	4/13/96	BIN-A 4/11-4/13	ND (0.5)
3/1/96	BIN-A -2/29-3/1	9.6	4/15/96	BIN-B 4/13-4/14	28
3/1/96	BIN-B -3/1	6.2	4/16/96	BIN-C 4/14-4/15	29
3/2/96	BIN-A -3/1-3/2	4			

Table G-4  
 Daily Composite Reactor Product Highest PCB Congener Content (in ppm)  
 During Full Scale Operation  
 (Page 1 of 3)

Date	Bin	PPM PCB	Date	Bin	PPM PCB
4/11/96	BIN-C 4/9-4/11	ND (2.0)	5/20/96	BIN-B 5/18-19	0.93
4/15/96	BIN-B 4/13-4/14	3.8	5/21/96	BIN-C 5/19-20	ND (0.5)
4/16/96	BIN-A 4/15-4/16	2.7	5/22/96	BIN-A 5/20-21	ND (0.5)
4/17/96	BIN-B 4/16	ND (0.5)	5/22/96	BIN-B 5/21-22	1.2
4/18/96	BIN-C 4/17-4/18	ND (0.5)	5/24/96	BIN-C 5/22-24	ND (0.5)
4/19/96	BIN-A 4/18-4/19	ND (0.5)	5/25/96	BIN-A 5/24-25	ND (0.5)
4/20/96	BIN-B 4/19-4/20	ND (0.5)	5/27/96	BIN-B 5/25-26	ND (0.5)
4/22/96	BIN-A 4/20-4/21	ND (0.5)	5/28/96	BIN-C 5/26-27	ND (0.5)
4/23/96	BIN-B 4/21-4/22	1.3	5/28/96	BIN-A 5/27	0.54
4/24/96	BIN-C 4/22-4/24	2.3	6/1/96	BIN-A 5/30-31	ND (0.5)
N-A GR	4/24 1400 HRS	ND (0.5)	6/1/96	BIN-B 5/31-6/1	ND (0.5)
4/25/96	BIN-A 4/24-4/25	ND (0.5)	6/3/96	BIN-C 6/1-2	ND (0.5)
n-b gra	4/24 0820hrs	ND (0.5)	6/5/96	BIN-A 6/3	ND (0.5)
n-b gra	4/24 1220hrs	ND (0.5)	6/5/96	BIN-B 6/4	ND (0.5)
4/26/96	BIN-C 4/25-4/26	ND (0.5)	6/7/96	BIN-C 6/5-6	ND (0.5)
4/26/96	BIN-B 4/25-4/26	0.5	6/8/96	BIN-A 6/7	ND (0.5)
4/28/96	BIN-A 4/26-7	1.7	6/8/96	BIN-B 6/7-8	ND (0.5)
4/28/96	BIN-B 4/27-8	0.92	6/11/96	BIN-C 6/8-11	ND (0.5)
4/29/96	BIN-A 4/29	1.6	6/12/96	BIN-A 6/11-12	ND (0.5)
4/29/96	BIN-C 4/29	0.73	6/14/96	BIN-B 6/12-13	ND (0.5)
5/2/96	BIN-B 5/1-2	ND (0.5)	6/17/96	BIN-C 6/13-14	ND (0.5)
5/4/96	BIN-C 5/2-3	0.51	6/18/96	BIN-A 6/16-17	ND (0.5)
5/6/96	BIN-A 5/3-5	0.59	6/20/96	BIN-B 6/17-18	ND (0.5)
5/6/96	BIN-B 5/5-6	ND (0.5)	6/20/96	BIN-C 6/18-19	ND (0.5)
5/7/96	BIN-C 5/6-7	ND (0.5)	6/24/96	BIN-A 6/21-22	ND (0.5)
5/8/96	BIN-A 5/7-8	ND (0.5)	6/24/96	BIN-B 6/22-24	ND (0.5)
5/9/96	BIN-B 5/8-9	ND (0.5)	6/26/96	BIN-C 6/24-26	ND (0.5)
5/11/96	BIN-C 5/9-10	1.4	6/28/96	BIN-A 6/26-27	ND (0.5)
5/13/96	BIN-A 5/10-11	ND (0.5)	6/29/96	BIN-B 6/27-28	ND (0.5)
5/13/96	BIN-B 5/11-12	ND (0.5)	7/1/96	BIN-C 6/28-30	ND (0.5)
5/14/96	BIN-C 5/12-14	ND (0.5)	7/3/96	BIN-A 7/1-2	ND (0.5)
5/16/96	BIN-A 5/14-15	1.2	7/6/96	BIN-B 7/2-3	ND (0.5)
5/16/96	BIN-B 5/15	ND (0.5)	7/6/96	BIN-C 7/3-5	ND (0.5)
5/17/96	BIN-C 5/16-17	ND (0.5)	7/8/96	BIN-A 7/6-7	ND (0.5)
5/18/96	BIN-A 5/17-18	ND (0.5)	7/10/96	BIN-B 7/7-9	ND (0.5)

**Table G-4**  
**Daily Composite Reactor Product Highest PCB Congener Content (in ppm)**  
**During Full Scale Operation**  
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Date	Bin	PPM PCB	Date	Bin	PPM PCB
7/16/96	BIN-C 7/10-11	ND (0.5)	10/21/96	BIN-B 10/18-20	ND (0.5)
7/16/96	BIN-A 7/14-15	ND (0.5)	10/23/96	BIN-C 10/20-22	ND (0.5)
7/20/96	BIN-B 7/17-19	ND (0.5)	10/29/96	BIN-B 10/23-26	ND (0.5)
7/23/96	BIN-C 7/20-22	ND (0.5)	10/31/96	BIN-C 10/26-31	ND (0.5)
7/27/96	BIN-B 7/23-25	ND (0.5)	11/4/96	BIN-B 10/31-11/3	ND (0.5)
7/27/96	BIN-A 7/25-27	ND (0.5)	11/12/96	BIN-B 11/4-6	ND (0.5)
7/31/96	BIN-C 7/27-30	ND (0.5)	11/30/96	BIN-A 11/26-28	ND (0.5)
8/3/96	BIN-A 7/30-8/1	ND (0.5)	12/1/96	BIN-B 11/28-30	ND (0.5)
8/5/96	BIN-B 8/1-8/3	ND (0.5)	12/3/96	BIN-C 11/30-12/2	ND (0.5)
8/7/96	BIN-C 8/4-7	ND (0.5)	12/6/96	BIN-A 12/3-5	ND (0.5)
8/12/96	BIN-B 8/9-12	ND (0.5)	12/9/96	BIN-B 12/5-8	ND (0.5)
8/11/96	BIN-A 8/7-9	ND (0.5)	12/13/96	BIN-C 12/8-10	ND (0.5)
8/16/96	BIN-C 8/12-15	ND (0.5)	12/13/96	BIN-A 12/10-13	ND (0.5)
8/18/96	BIN-A 8/15-17	ND (0.5)	12/16/96	BIN-B 12/13-15	ND (0.5)
8/20/96	BIN-B 8/18-20	ND (0.5)	12/19/96	BIN-C 12/15-17	ND (0.5)
8/23/96	BIN-A 8/20-22	ND (0.5)	12/23/96	BIN-A 12/17-20	ND (0.5)
8/25/96	BIN-B 8/22-24	ND (0.5)	12/23/96	BIN-C 12/20-22	ND (0.5)
8/28/96	BIN-C 8/24-26	ND (0.5)	12/26/96	BIN-B 12/23-24	ND (0.5)
8/31/96	BIN-A 8/27-29	ND (0.5)	12/28/96	BIN-C 12/25-27	ND (0.5)
9/03/96	BIN-B 8/29-9/1	ND (0.5)	1/1/97	BIN-A 12/27-29	ND (0.5)
9/09/96	BIN-A 9/6-7	ND (0.5)	1/1/97	BIN-B 12/29-31	ND (0.5)
9/10/96	BIN-B 9/7-9	ND (0.5)	1/4/97	BIN-C 12/1-1/2	ND (0.5)
9/13/96	BIN-C 9/9-11	ND (0.5)	1/6/97	BIN-A 1/2-1/4	ND (0.5)
9/13/96	BIN-A 9/9-11	ND (0.5)	1/9/97	BIN-B 1/4-1/6	ND (0.5)
9/17/96	BIN-B 9/13-15	ND (0.5)	1/10/97	BIN-B 1/6-1/8	ND (0.5)
9/17/96	BIN-A 9/16-17	ND (0.5)	1/13/97	BIN-A 1/9-1/12	ND (0.5)
9/20/96	BIN-C 9/17-20	ND (0.5)	1/16/97	BIN-B 1/12-1/15	ND (0.5)
9/27/96	BIN-A 9/20-22	ND (0.5)	1/20/97	BIN-A 1/15-1/18	ND (0.5)
10/1/96	BIN-B 9/25-29	ND (0.5)	1/23/97	BIN-B 1/19-1/21	ND (0.5)
10/4/96	BIN-C 9/29-10/3	ND (0.5)	1/25/97	BIN-A 1/22-1/25	ND (0.5)
10/8/96	BIN-A 10/3-5	ND (0.5)	1/30/97	BIN-B 1/25-1/29	ND (0.5)
10/10/96	BIN-B 10/5-8	ND (0.5)	2/3/97	BIN-A 1/30-2/1	ND (0.5)
10/14/96	BIN-C 10/8-12	ND (0.5)	2/6/97	BIN-B 2/2-2/4	ND (0.5)
10/15/96	BIN-B 10/12-14	ND (0.5)	2/8/97	BIN-A 2/5-2/7	ND (0.5)
10/18/96	BIN-C 10/15-18	ND (0.5)	2/12/97	BIN-B 2/7-2/10	ND (0.5)

**Table G-4**  
**Daily Composite Reactor Product Highest PCB Congener Content (in ppm)**  
**During Full Scale Operation**  
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Date	Bin	PPM PCB
2/15/97	BIN-A 2/10-2/13	ND (0.5)
2/17/97	BIN-B 2/13-2/16	ND (0.5)
2/20/97	BIN-A 2/16-2/19	ND (0.5)
2/22/97	BIN-B 2/19-2/21	ND (0.5)
2/26/97	BIN-A 2/22-2/26	ND (0.5)
3/2/97	BIN-B 2/26-3/2	1.2
3/6/97	BIN-A 3/2-5	0.83
3/10/97	BIN-B 3/5-9	ND (0.5)
3/13/97	BIN-A 3/9-13	ND (0.5)
3/18/97	BIN-B 3/13-17	ND (0.5)
3/20/97	BIN-A 3/17-20	0.56
3/25/97	BIN-B 3/20-25	ND (0.5)
3/30/97	BIN-A 3/25-28	ND (0.5)
4/02/97	BIN-B 3/28-31	ND (0.5)
4/07/97	BIN-A 4/1-4	ND (0.5)
4/07/97	BIN-B 4/4	ND (0.5)
4/15/97	BIN-B 4/11-15	ND (0.5)
4/21/97	BIN-A 4/15-20	ND (0.5)
4/24/97	BIN-B 4/20-23	ND (0.5)
4/28/97	BIN-A 4/23-26	ND (0.5)
4/30/97	BIN-B 4/27-29	ND (0.5)
5/1/97	BIN-A 4/29-5/1	ND (0.5)
5/5/97	BIN-B 5/2-4	ND (0.5)
5/7/97	BIN-A 5/4-6	ND (0.5)
5/7/97	BIN-B 5/6-7	ND(0.5)

## **APPENDIX H**

### **ACRONYMS**

## ***List of Acronyms***

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<b><i>Acronym</i></b>	<b><i>Title</i></b>
°F	degrees Fahrenheit
acfm	actual cubic feet per minute
APC	Air Pollution Control
APCS	Air Pollution Control System
APEG	Alkali Polyethylene Glycol
BCDP	Base Catalyzed Decomposition Process
Btu	British thermal unit
cfm	cubic feet per minute
CPVC	chlorinated polyvinyl chloride
DOE	U.S. Department of Energy
DRE	Destruction Removal Efficiency
dscf	dry standard cubic feet
dscfm	dry standard cubic feet per minute
EPA	U.S. Environmental Protection Agency
exp	the exponential function
gpm	gallon(s) per minute
HEME	High Efficiency Mist Eliminator
ID	Induced Draft (Fan)
IT	IT Corporation
KOH	potassium hydroxide
KPEG	potassium polyethylene glycol
lbs/hr	pounds per hour
LEL	Lower Explosive Limit
Ln	Natural logarithm
MOC	Minimum Oxygen Concentration
NCEL	Naval Civil Engineering Laboratory
NEESA	Naval Energy and Environmental Support Activity
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
NPSH	net positive suction head
NRMRL	National Risk Management Research Laboratory (formally RREL)
OSHA	Occupational Safety and Health Administration
P&ID	Piping and Instrumentation Diagram
PACDIV	Pacific Division, Naval Facilities Engineering Command
PCB	polychlorinated biphenyl
PEG	polyethylene glycol
PFD	Process Flow Diagram
PNNL	Pacific Northwest National Laboratory

## ***List of Acronyms (continued)***

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<b><i>Acronym</i></b>	<b><i>Title</i></b>
ppb	parts per billion
ppm	parts per million
ppmv	parts per million by volume
psi	pounds per square inch
psia	pounds per square inch absolute
psig	pounds per square inch gage
PUF	Polyurethane foam
R&D	Research and Development
RCRA	Resource Conservation and Recovery Act
RKR	Rotary Kiln Reactor
rpm	revolution(s) per minute
RREL	Risk Reduction Engineering Laboratory
scfm	standard cubic feet per minute
SFPE	Society for Fire Protection Engineers
STR	Stirred Tank Reactor
TEQ	Toxic Equivalent
tph	ton(s) per hour
TR	Transformer Rectifier
TSCA	Toxic Substances Control Act
VOC	volatile organic compound
WESP	Wet Electrostatic Precipitator
WWTP	wastewater treatment plant